THE QUALITY OF SELECTED WATERS IN THE TOWNSHIP OF FOLEY

1975

The Honourable
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Ministry
of the
Environment

Ontario

A REPORT ON

THE QUALITY OF SELECTED WATERS

IN THE TOWNSHIP OF FOLEY

PARRY SOUND DISTRICT

1975.

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SUMMARY AND CONCLUSIONS

In general, the waters studied exhibited the low chemical concentrations typical of Precambrian Shield Lakes. Although the data are not entirely in agreement in that different variables indicate somewhat varying degrees of trophic status, the results as a whole indicate a mesotrophic status for all the study waters. The relatively high concentrations of total phosphorus in certain areas, the generalized low dissolved oxygen concentrations in the bottom waters at deeper stations, and the low pH values recorded in the bottom waters of Otter lake are of major concern.

Much of the shoreline in the study area is steep and rocky with only a thin veneer of soils typical of the Precambrian Shield. Adequate treatment of domestic wastes by conventional septic-tank-tile-field systems is often difficult, if not impossible in this type of terrain.

Due to their inherent dilute nature and mesotrophic status, all of the study waters are very vulnerable to artificial inputs of nutrients. Nutrient inputs from shoreline facilities could easily degrade the existing water quality and render the waters less desirable for recreational pursuits. Based on the "Lake Alert" rankings and chlorophyll a and Secchi disc relationships, lakes Haines, Oastler and Little Otter appear the most susceptible to water quality impairment induced by lakeshore development and associated waste disposal.

RECOMMENDATIONS

Based on the findings of this report, it is recommended that:

1. The chlorophyll a - Secchi disc programme be continued to further substantiate the findings of this report and to document changes in the trophic status over the long term.
2. Caution be exercized in the approval of future shoreline development that might have a tendency to undermine the quality of the various waters.

1.0 INTRODUCTION

In recent years, a greater awareness of water pollution problems within the public sector has resulted in an increasing number of requests for water quality assessments of recreational lakes. Correspondingly, a need was established for a simple, yet effective, method of evaluating lake water quality.

In response to this need, the Secchi Disc - chlorophyll *a* "Self-Help" programme involving a cooperative approach between the Ministry of the Environment and the public was developed. Under this format, concerned citizens assume the responsibility of collecting weekly data on Secchi disc depths (a measure of water clarity) and chlorophyll *a* concentrations (a measure of algal abundance) throughout the ice free season. Analytical and interpretive services are provided by the Ministry of the Environment. The initial year's data from a "Self Help" programme provide a base from which future trends and changes may be determined, therefore the maximum value of such a programme is only realized when it is continued for a number of years.

Since its implementation in 1971, the "Self Help" programme has proved a valuable tool in water quality evaluation throughout the province.

1.1 PURPOSE AND SCOPE

During 1972, concern was expressed through Foley Township Council regarding the quality of waters in the area. Subsequently, seven study lakes were selected and a Secchi disc - chlorophyll *a* monitoring programme was established with sampling commencing in the spring of 1973. In addition to the seven selected lakes, a small portion of Georgian Bay was monitored.

In conjunction with the "Self Help" programme, a detailed investigation of water quality was carried out in mid-summer by staff of the Biology Section.

The following report presents the results of the 1973 study.

1.2 DESCRIPTION OF THE STUDY AREA

The study area is located in the District of Parry Sound within the Precambrian Shield area of Ontario. The seven lakes studied - Haines, Horseshoe, McLaren, Oastler, Otter, Little Otter and Rankin, range in size from 68 to 506 ha and all are wholly or partially in the Township of Foley. As well, the portion of Georgian Bay studied borders on Foley Township. Figures 1.2.1 (a), (b) and (c) are sketch maps of the study area showing the locations of sampling stations. A summary of morphological characteristics of the study lakes is provided in Table 1.2.1 below:

TABLE 1.2.1

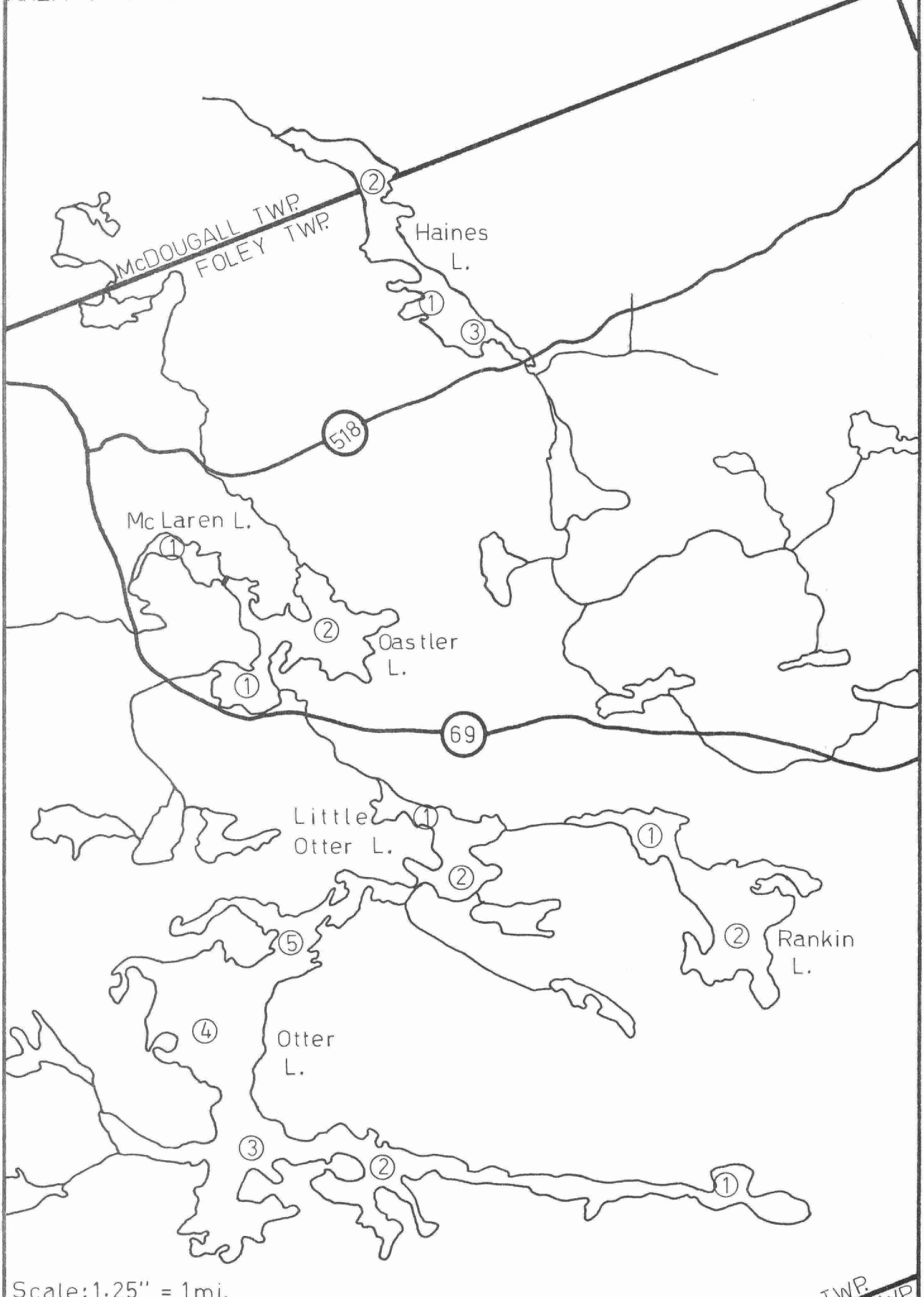
MORPHOLOGICAL CHARACTERISTICS OF STUDY LAKES

	SURFACE AREA		MAXIMUM DEPTH		MEAN DEPTH		VOLUME	
	Hectares	Acres	Metres	Feet	Metres	Feet	Metres	Acre-Feet
Haines	112	277	19.2	63	8.4	27.4	9.41×10^6	7.61×10^3
Horseshoe	370	914	20.4	67	6.5	21.4	2.40×10^7	1.96×10^4
Oastler	116	286	18.9	62	7.4	24.4	8.58×10^6	6.97×10^3
Otter	506	1250	44.8	147	10.8	35.5	5.46×10^7	4.44×10^4
Little Otter	68	168	5.2	17	2.7	8.9	1.83×10^6	1.49×10^3
Rankin	140	346	20.1	66	7.8	25.7	1.09×10^7	8.91×10^3

NOTE: 1. Data provided by Ministry of Natural Resources, Parry Sound.

2. Data not available for McLaren Lake or studied portion of Georgian Bay.

FIG. 1.2.1 (a) SKETCH MAP OF THE STUDY AREA SHOWING THE LOCATIONS OF SAMPLING STATIONS



Scale: 1.25" = 1 mi.
Note: Little Otter Lake stn 2 - chemical data only.
Otter Lake stn. 5 - Chlorophyll - Secchi disc data only.

FIG. 1.2.1(b) SKETCH MAP OF THE STUDY AREA SHOWING THE LOCATIONS OF SAMPLING STATIONS

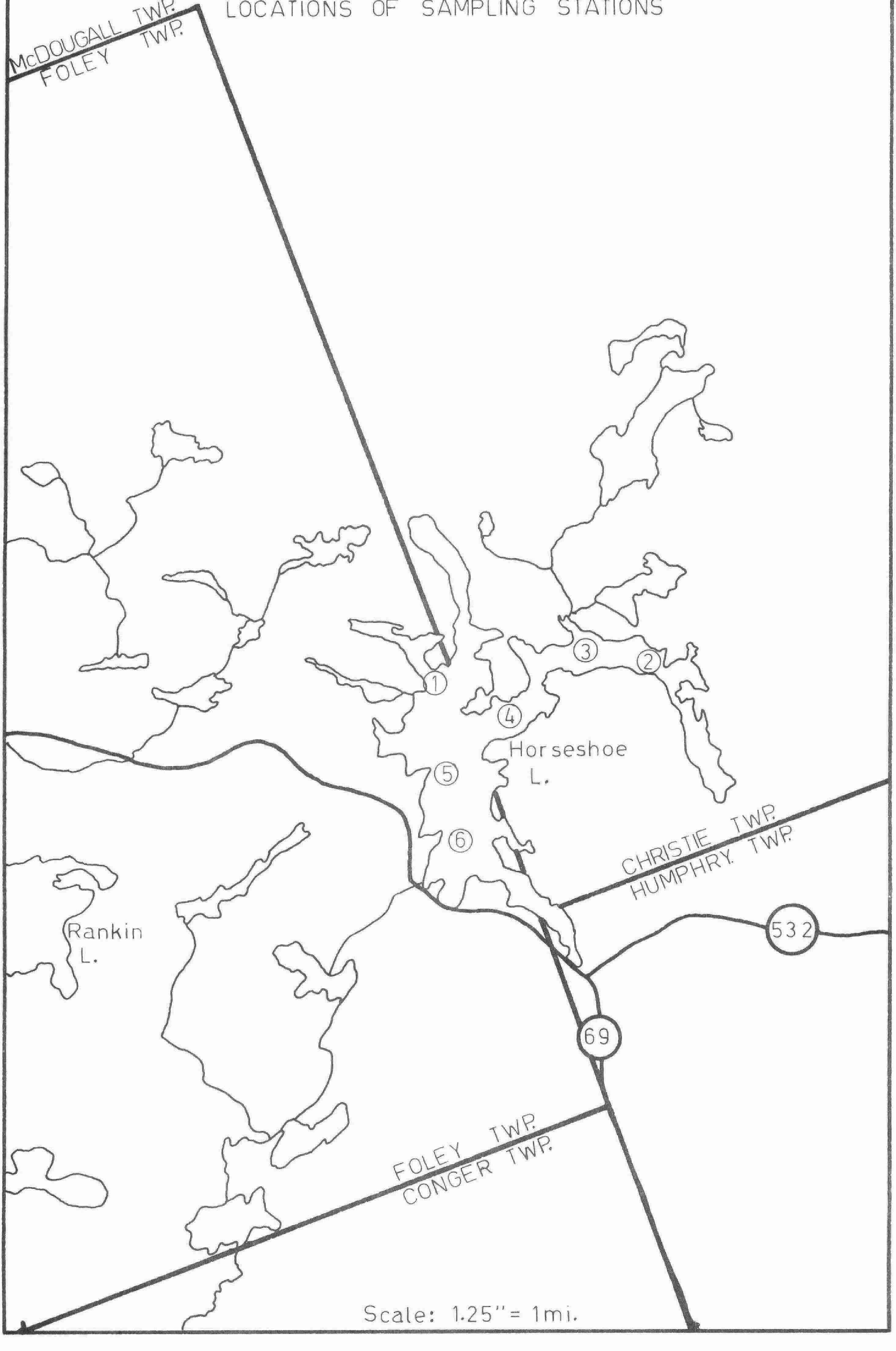
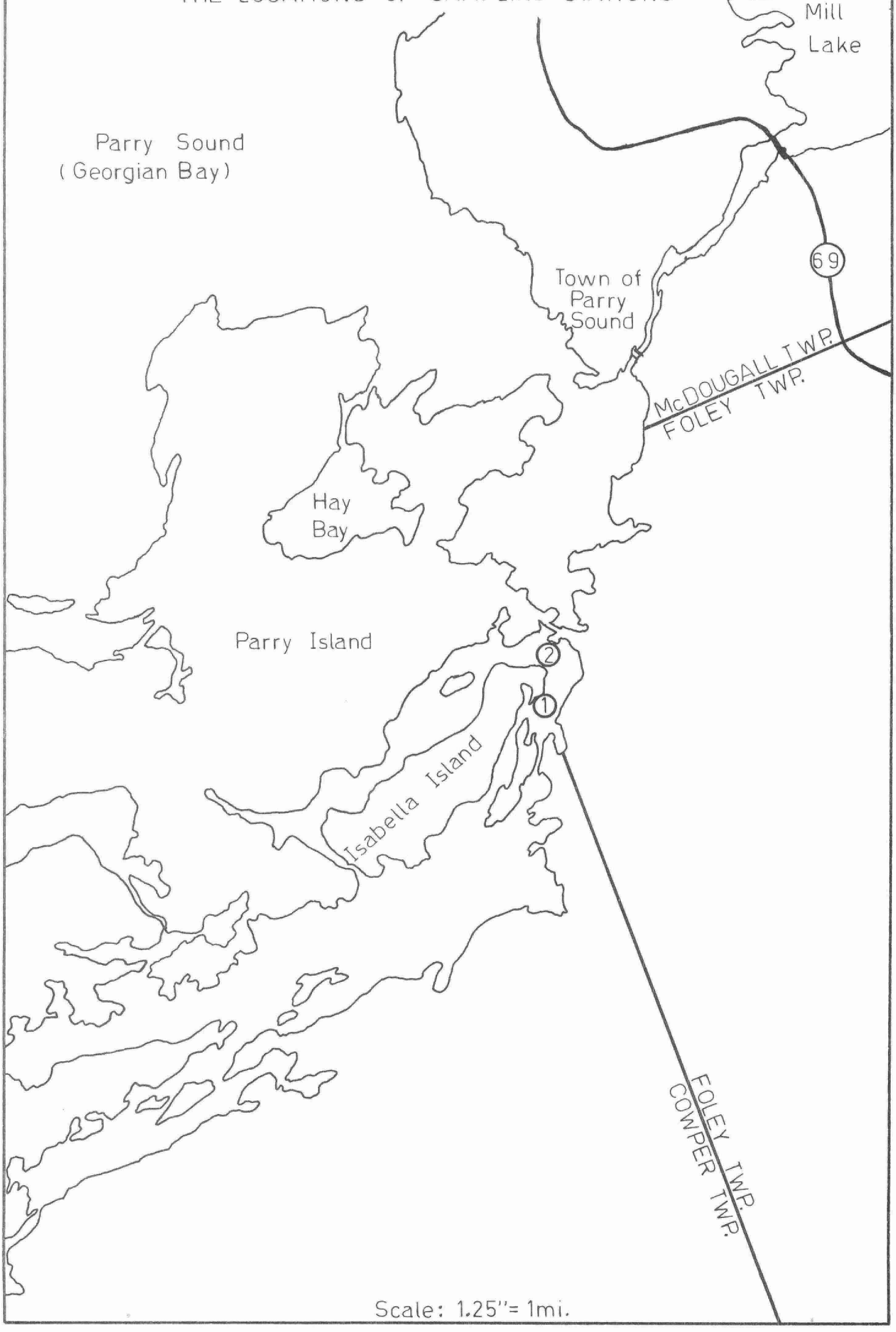


FIG. 1.2.1(c) SKETCH MAP OF THE STUDY AREA SHOWING THE LOCATIONS OF SAMPLING STATIONS



2.0 METHODS

2.1 PHYSICO-CHEMICAL

During August, duplicate samples were collected with a Van Dorn sampler from one m below surface and one m above bottom at each sampling location. Samples were retained in a portable cooler during transportation to the field laboratory where pH and conductivity measurements were made. Subsequently, samples were shipped to the Ministry of the Environment laboratory for analyses including:

alkalinity	calcium	nitrogen
hardness	potassium	phosphorous
sulphate	sodium	iron
	magnesium	

Temperature and dissolved oxygen depth distributions were determined in the field.

2.2 SECCHI DISC AND CHLOROPHYLL a

At weekly intervals throughout the summer, stations were sampled for Secchi disc transparency and chlorophyll a concentrations.

Secchi disc readings were taken by lowering the disc (20 cm in diameter with alternating black and white quadrants) to the depth at which it just disappeared. The depth was recorded and the disc is raised to the point at which it reappeared and that depth is recorded. The point halfway between these two readings was the Secchi disc transparency depth.

Chlorophyll a samples were collected as composites through the euphotic zone (zone of significant light penetration - taken as twice the Secchi disc depth). A composite sample is collected by lowering a one l glass bottle in a weighted sampler to a depth equal to twice the Secchi disc reading and then retrieving it at such a rate to allow complete filling as it reaches surface - the object being to collect water equally from all

portions of the measured sampling column. Figures 2.2.1 and 2.2.2 are schematic representations of the methology of composite sampling and the composite sampler respectively.

Samples for chlorophyll a analyses were immediately stabilized with sufficient magnesium carbonate solution (2% weight to volume ratio) to elevate the pH and retard the breakdown of chlorophyll a during transportation. Samples were shipped to Toronto and analysed in the Ministry of the Environment laboratory within 48 hours of the time of receipt.

FIGURE 2.2.1

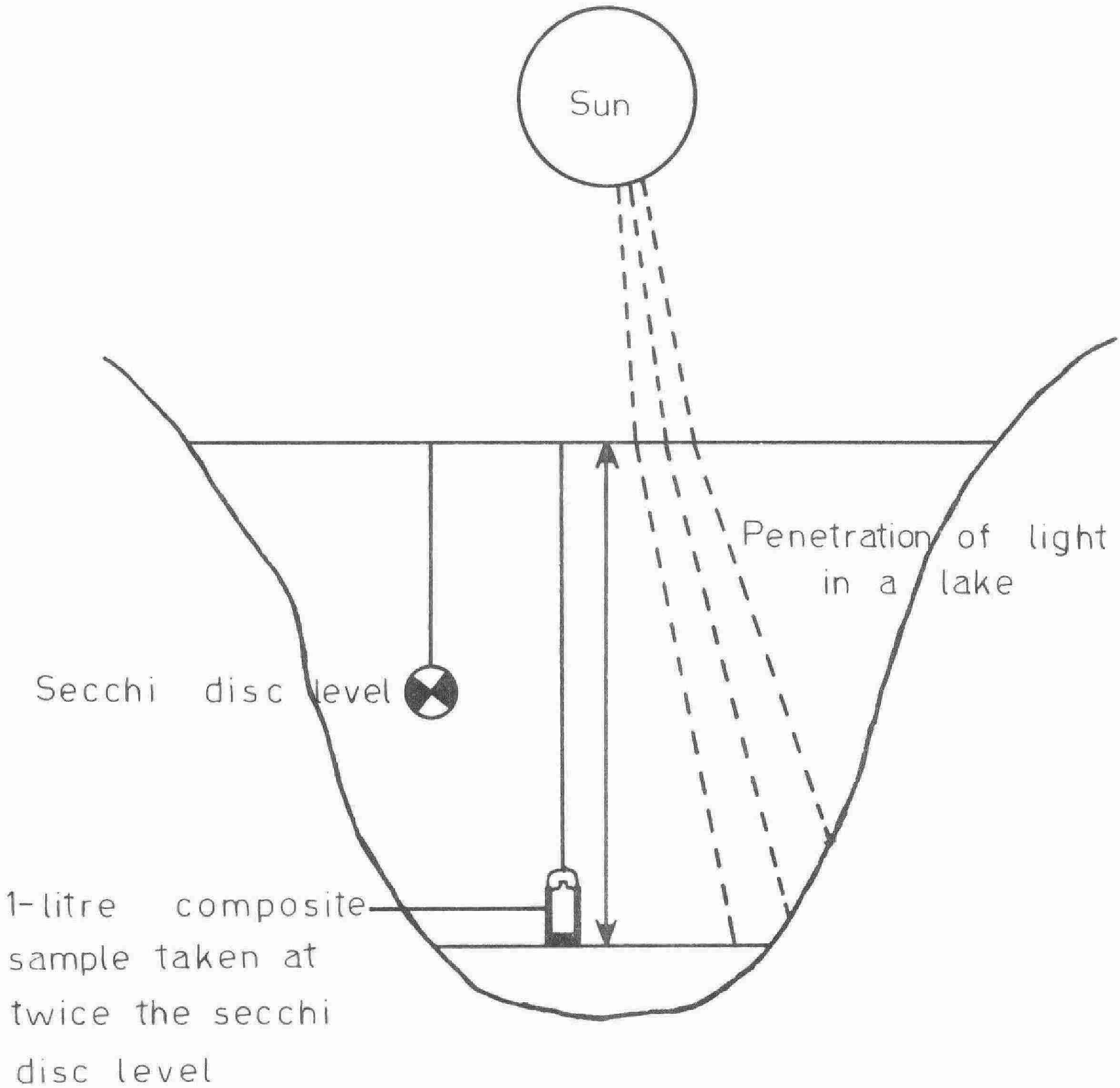
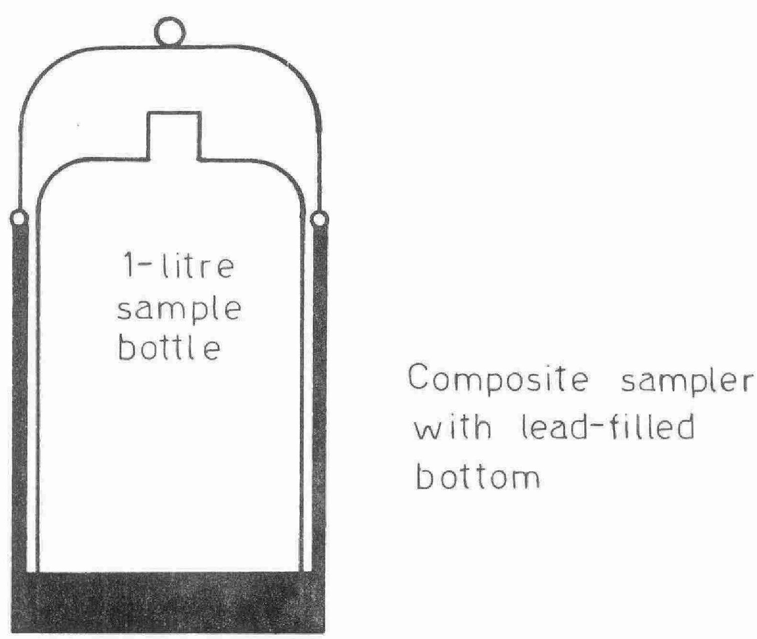


FIGURE 2.2.2



3.0 RESULTS

3.1 PHYSICO-CHEMICAL

The results of chemical analyses are provided in Tables I and II of Appendix B. Since basic differences in water chemistry exist between the inland lakes and Georgian Bay, the results for these areas are presented under separate headings.

pH, ALKALINITY, HARDNESS, AND CONDUCTIVITY

Table 3.1.1, below, provides a summary of ranges and mean values of pH, alkalinity, hardness and conductivity in the study area.

TABLE 3.1.1

RANGES AND MEAN VALUES - pH, ALKALINITY, HARDNESS, AND CONDUCTIVITY

Lake	pH		Alkalinity ($mg\ l^{-1}\ CaCO_3$)		Hardness ($mg\ l^{-1}\ CaCO_3$)		Conductivity ($umho\ cm^{-1}$)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Haines	6.11-7.17	6.66	7-11	9	16-20	18	62-69	58
Horseshoe	6.44-7.64	7.12	7-15	11	16-21	17	45-85	53
McLaren	7.25-7.59	7.42	10-11	10.5	-----	20	60-61	60.5
Oastler	6.34-7.31	6.92	10-13	12	17-20	19	53-69	59.5
Otter	5.46-6.27	5.84	8-18	12	14-20	17.5	31-43	33
Little Otter	6.25-6.40	6.34	8-12	10	18-20	19	52-60	56
Rankin	6.15-7.11	6.64	8-11	9.5	22-25	23	56-58	57
Georgian Bay	7.13-7.62	7.39	23-28	26	36-39	37.5	76-84	80

Study Lakes

Individual pH values for the study lakes varied from 5.46 to 7.64 with surface samples generally exhibiting significantly higher pH's than bottom samples. Only Otter Lake had an overall mean pH (considering all stations and depths) below 6.0 (5.84). Haines, Oastler, Little Otter and Rankin lakes exhibited mean pH values between 6.0 and 7.0 (6.66, 6.92, 6.34 and 6.64 respectively) while mean values for Horseshoe and McLaren lakes were 7.12 and 7.42 respectively.

Alkalinity ranged from 7 to 18 mg l^{-1} in the study lakes. Significant variation with depth was evident with alkalinity highest in bottom samples in the majority of cases. Overall mean alkalinities of 9, 11, 10.5, 12, 12, 10 and 9.5 mg l^{-1} were recorded in Haines, Horseshoe, McLaren, Oastler, Otter, Little Otter and Rankin Lakes respectively.

Hardness varied from 14 to 25 mg l^{-1} and as with alkalinity, the highest values generally occurred in bottom samples. Only Rankin Lake (overall mean - 24 mg l^{-1}) exhibited hardness values exceeding 20 mg l^{-1}. The remaining lakes had mean values within the range 17.5 to 20 mg l^{-1} (18, 18, 20, 19, 17.5 and 19 mg l^{-1} respectively at Haines, Horseshoe, McLaren, Oastler, Otter and Little Otter Lakes).

Conductivity showed a wide range (31 to 85 μmho cm^{-1}) in the study lakes, however, almost all values were within the range 45 to 60 μmho cm^{-1}. The highest conductivity (85 μmho cm^{-1}) was recorded in the bottom waters of Horseshoe Lake (station 6) while the lowest conductivities (range 31 to 43 μmho cm^{-1}) were recorded in Otter Lake (all stations and depths). Haines, Horseshoe, McLaren, Oastler, Otter, Little Otter and Rankin Lakes exhibited mean conductivities of 58, 53, 60.5, 59.5, 33, 56, and 57 μmho cm^{-1} respectively). A slight tendency toward higher conductivity in bottom water samples was observed.

Georgian Bay

As indicated in Table 3.1.1, pH, alkalinity, hardness and conductivity were very similar between stations 1 and 2. pH ranged from 7.13 to 7.62, alkalinity from 23 to 28 mg l^{-1}, hardness from 36 to 39 mg l^{-1} and conductivity from 76 to 84 µmho cm^{-1}. pH at surface was slightly higher than in the bottom waters, while alkalinity, hardness, and conductivity were slightly higher in the bottom waters.

MAJOR CATIONS:

A summary of mean concentrations and ranges in concentration of the major cations - calcium, magnesium, sodium, and potassium is provided in Table 3.1.2 below.

TABLE 3.1.2

RANGES AND MEAN VALUES - MAJOR CATIONS

Lake	Calcium		Magnesium		Sodium		Potassium	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Haines	4-5	4.5	1-2	1.5	---	3	1.2-1.3	1.2
Horseshoe	4-6	4.5	1-2	1.5	3-6	3.5	1.0-1.4	1.2
McLaren	---	6	---	1	3	3	---	1.2
Oastler	4-5	4.5	1-2	2	3-4	3	1.0-1.1	1.1
Otter	3-6	4.0	1-2	1.5	1-2	1	.9-1.3	1.25
Little Otter	4-6	4.5	1-2	2	3-4	3	1.2-1.3	1.25
Rankin	6-7	6	1-2	2	---	3	1.1-1.2	1.15
Georgian Bay	10-11	11	2-3	2.5	---	2	1.0-1.1	1.1

Note: Values expressed in mg l^{-1}

Study Lakes

Concentrations of calcium in the study lakes varied from 3 to 7 mg l^{-1} however, most values were within the range 4 to 6 mg l^{-1}. Generally, calcium was slightly higher in McLaren and Rankin Lakes (means 6 mg l^{-1}) and slightly lower in Otter Lake (mean 4.0 mg l^{-1}), than in the remaining study lakes (means 4.5 mg l^{-1}).

Concentrations of sodium ranged from 1 to 6 mg l^{-1}. Notwithstanding this wide range, sodium concentrations were quite uniform with nearly all values within the range 3-4 mg l^{-1}. Exceptions occurred in Otter Lake (range 1-2 mg l^{-1}) and in the bottom waters of station 6 - Horseshoe Lake (6 mg l^{-1}).

Concentrations of magnesium and potassium in the study lakes were very uniform with all lakes exhibiting values within the ranges 1 to 2 mg l^{-1} and .9 to 1.4 mg l^{-1} for magnesium and potassium respectively.

Georgian Bay

Concentrations of the major cations showed little variation with depth or between stations in Georgian Bay. Calcium, magnesium, sodium, and potassium had mean concentrations of 11, 2.5 and 1.1 mg l^{-1} respectively.

MAJOR NUTRIENTS

Nitrogen

A summary of nitrogen concentrations in the study area is provided in Table 3.1.3.

TABLE 3.1.3

RANGES AND MEAN VALUES - NITROGENS

	Free Ammonia		Total Kjeldahl		Nitrate		Nitrate	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
HAINES	<.01-.05	.03	.24-.40	.33	<.01-.24	.09	.002-.005	.003
HORSESHOE	<.01-.41	.06	.25-.78	.39	<.01-.10	.02	.001-.009	.003
McLAREN	<.01-.02	.01	.28-.36	.32	-------	.01	---------	.002
OASTLER	<.01-.19	.06	.28-.52	.37	-------	.01	.002-.012	.005
OTTER	<.01-.13	.03	.19-.44	.28	<.01-.17	.08	.001-.005	.003
LITTLE OTTER	.01-.02	.01	.24-.38	.29	.03-.06	.04	---------	.001
RANKIN	.01-.03	.02	.27-.36	.31	<.01-.13	.07	.001-.005	.003
GEORGIAN BAY	.04-.06	.05	.30-.40	.34	<.01-.08	.04	.003-.004	.003

Note: Values expressed in mg l^{-1}.

Study Lakes:

Concentrations of free ammonia ranged from <.01 to .41 mg l^{-1} with most values less than .01 mg l^{-1}. The highest ammonia concentrations were recorded in the bottom waters of Horseshoe Lake - stations 1 and 6 (.26 and .41 mg l^{-1} respectively), Oastler Lake - station 2 (.19 mg l^{-1}) and Otter Lake - station 1 (.13 mg l^{-1}).

Total kjeldahl nitrogen concentrations were fairly uniform with overall mean values for the study lakes ranging from .29 to .39 mg l^{-1}. The highest concentrations of kjeldahl nitrogen occurred at the locations which exhibited elevated concentrations of free ammonia (Horseshoe Lake - stations 1 and 6; Oastler Lake - station 2; and Otter Lake - station 1) where Kjeldahl nitrogen concentrations of .72, .78, .52, and .44 mg l^{-1} respectively were recorded.

Nitrate concentrations varied from <.01 to .24 mg l^{-1} with most values falling considerably below .10 mg l^{-1} . Haines, Otter and Rankin Lakes exhibited the highest concentrations of nitrate (mean concentrations of .09,.08, and .07 mg l^{-1} respectively) while McLaren and Oastler Lakes exhibited the lowest concentrations (.01 and <.01 mg l^{-1} respectively). Horseshoe and Little Otter Lakes had mean nitrate concentrations of .02 and .04 mg l^{-1} respectively.

Concentrations of nitrite varied from .001 to .012 mg l^{-1} however, except for values of .009 and .012 mg l^{-1} recorded in the bottom waters of Horseshoe Lake (station 6) and Oastler Lake (station 2) respectively, all values were .005 mg l^{-1} or less.

Georgian Bay

Mean concentrations of free ammonia, kjeldahl nitrogen, nitrate and nitrite were .05,.34,.04, and .003 mg l^{-1} respectively. No significant variation with depth was observed, however, a tendency toward slightly higher nitrogen concentrations was noted at station 2.

Phosphorous

Phosphorous concentrations in the study area are summarized in Table 3.1.4.

TABLE 3.1.4

RANGES AND MEAN VALUES - PHOSPHOROUS

Lake	Total Range	Total Mean	Soluble Range	Soluble Mean
Haines	.010-.026	.016	.001-.006	.002
Horseshoe	.007-.030	.015	.001-.009	.003
McLaren	.010-.016	.013	---------	.002
Oastler	.009-.038	.019	.001-.012	.005
Otter	.003-.023	.011	.001-.016	.003
Little Otter	.010-.027	.016	.001-.002	.001
Rankin	.015-.025	.021	.001-.007	.004
Georgian Bay	.013-.019	.015	.002-.005	.004

Note: values expressed in mg l^{-1}

Study Lakes

Concentrations of total phosphorous ranged from .003 to .038 mg l^{-1} with the highest concentrations evident in the bottom waters. Oastler and Rankin Lakes exhibited the highest mean concentrations of total phosphorous (.019 and .021 mg l^{-1} respectively) while McLaren and Otter Lakes (means of .013 and .011 mg l^{-1} respectively) exhibited the lowest concentrations. Haines, Horseshoe and Little Otter Lakes had mean phosphorous concentrations of .016, .015 and .016 mg l^{-1} respectively.

Soluble phosphorous concentrations ranged from .001 to .016 mg l^{-1}, however, most values were below .005 mg l^{-1}. Values exceeding .005 mg l^{-1} were recorded at Haines Lake - station 1 (surface - .006 mg l^{-1}), Horseshoe Lake -

station 2 (surface - .009 mg l^{-1}), Oastler Lake - station 2 (bottom - .012 mg l^{-1}), Otter Lake - station 2 (bottom - .016 mg l^{-1}) and Rankin Lake - Station 2 (surface - .006 mg l^{-1}, bottom - .007 mg l^{-1}).

Georgian Bay

Concentrations of total and soluble phosphorus ranged from .013 to .019 and .002 to .005 mg l^{-1} respectively. No significant variation with station or depth was apparent.

SULPHATE

Study lakes

Concentrations of sulphate in the study lakes ranged from 7 to 10 mg l^{-1}. No significant pattern of variation was evident.

Georgian Bay

The concentration of sulphate in Georgian Bay was uniformly 10 mg l^{-1}.

IRON

Study Lakes

Concentrations of total iron ranged from .05 to 3.0 mg l^{-1} . In most cases, bottom waters were significantly higher in iron than surface waters. Haines, Horseshoe and Oastler Lakes exhibited the highest concentrations of total iron (mean values of .45, .48 and .52 mg l^{-1} respectively while McLaren, Otter and Little Otter Lakes exhibited the lowest concentrations (means of .12, .11, and .17 mg l^{-1} respectively). Rankin lake had a mean total iron concentration of .30 mg l^{-1} - intermediate in comparison to the other study lakes.

Concentrations of soluble iron ranged from .05 to 1.0 mg l^{-1} with most values falling below .15 mg l^{-1}. The highest soluble iron concentrations occurred at the locations exhibiting high concentrations of total iron.

Georgian Bay

Concentrations of total and soluble iron ranged from .05 to .20 and <.05 to .05 mg l^{-1} respectively.

TEMPERATURE AND DISSOLVED OXYGEN

The results of temperature and dissolved oxygen measurements on the study lakes and Georgian Bay are provided in Table III of Appendix B. Temperature and dissolved oxygen depth distributions are depicted in Figure I of Appendix C.

Temperature

Study Lakes

Surface temperatures in the study lakes were relatively constant ranging from 20.2 to 24.0° C and thermal stratification was evident at all locations with sufficient depth to permit formation of a thermocline.

In Haines, Otter and Rankin Lakes, thermoclines were established between 3 and 8 metres, 5 and 12 metres and 4 and 11 metres respectively.

Horseshoe Lake exhibited a thermocline between 6 and 13 metres at the deeper stations (1 and 6) while station 2 was too shallow to show thermal stratification. At the remaining stations (3, 4 and 5) thermoclines commenced at 4 to 6 metres and extended to bottom.

Oastler Lake exhibited a thermocline between 4 metres and bottom (6 metres) at station 1 and between 5 and 12 metres at station 2.

Little Otter and McLaren Lakes lacked sufficient depth to show evidence of thermal stratification.

It should be noted that the lower limit of the thermocline in most cases was quite indistinct with the rate of temperature decrease per unit depth in the upper hypolimnion often only slightly below that in the lower thermocline.

Georgian Bay

Surface temperatures at both stations were 24°C and little decrease with depth was noted. At the deeper location - station 2 (13m) only a three degree difference between the surface (24°C) and bottom (21°C) temperature was measured.

Dissolved Oxygen

Study Lakes

Distributions of dissolved oxygen in the study lakes were essentially clinograde (decreasing with depth) at all deeper stations while shallower stations exhibited orthograde dissolved oxygen distributions (essentially non diminishing with depth).

Although clinograde dissolved oxygen distributions were evident at all deeper stations, several (Horseshoe Lake - station 1, Otter Lake - station 1 and Rankin Lake - station 3) exhibited dissolved oxygen profiles which could also be termed positive heterograde based on a maximum dissolved oxygen concentration in their mid-water (metalimnetic) areas. Mid-water increases in dissolved oxygen were also evident at Haines Lake - stations 1 and 2, Horseshoe Lake - station 6, and Oastler Lake - station 2, however, concentrations in the metalimnetic areas remained considerably lower than those recorded near surface.

McLaren Lake, Little Otter Lake and the shallowest stations in Horseshoe Lake (2 and 3) exhibited abundant dissolved oxygen in the bottom waters (8.3 to 10.5 mg l^{-1}) while the bottom waters of Haines Lake, Oastler Lake, Rankin Lake and the deeper stations in Horseshoe Lake exhibited low concentrations of dissolved oxygen (range .7 to 5.5 mg l^{-1}). At most of the deeper stations, concentrations of dissolved oxygen were considerably below 4 mg l^{-1}.

Otter Lake showed a low bottom water dissolved oxygen concentration at station 1 (1.0 mg l^{-1}) however, at stations 2,3 and 4 (also deep) dissolved oxygen was abundant in the bottom waters (7.2 to 10.8 mg l^{-1}).

Georgian Bay

Dissolved oxygen distributions were slightly clinograde at both stations, showing a relatively constant decrease with depth, however, dissolved oxygen remained abundant in the bottom waters.

3.2 SECCHI DISC AND CHLOROPHYLL a

The results of Secchi disc and chlorophyll a monitoring on the study lakes and Georgian Bay are provided in Table IV of Appendix B. A summary of Secchi disc and chlorophyll a data is provided in Table 3.2.1.

TABLE 3.2.1

RANGES AND MEAN VALUES - SECCHI DISC AND CHLOROPHYLL a

Lake	Secchi Disc (metres)		Chlorophyll a ($\mu g\ l^{-1}$)	
	Range	Mean	Range	Mean
Haines	2.1-4.0	2.9	1.0-8.0	3.4
Horseshoe	2.4-6.0	4.3	1.0-10.5	3.1
McLaren	1.6-3.9	3.0	1.0-2.8	1.8
Oastler	1.8-3.6	2.7	1.0-4.3	2.6
Otter	3.6-5.6	4.3	0.2-3.7	1.9
Little Otter	2.0-3.8	3.2	0.9-3.5	2.2
Rankin	3.6-5.8	4.7	1.0-4.0	2.3
Georgian Bay	2.1-3.9	3.2	.7-4.7	2.6

Secchi Disc

Study Lakes

Mean Secchi disc readings in the study lakes varied from 2.9 to 4.7 metres. Mean Secchi disc readings of 3 metres or less were recorded in Haines, McLaren and Oastler Lakes (2.9, 3.0 and 2.7 metres respectively) while Horseshoe, Otter and Rankin Lakes exhibited mean Secchi disc transparencies of 4 metres or greater (4.3, 4.3 and 4.7 metres respectively). Little Otter Lake had a mean Secchi disc transparency of 3.2 m.

Georgian Bay

Secchi disc readings in Georgian Bay ranged from 2.1 to 3.9 metres with a overall mean of 3.2 metres.

Chlorophyll a

Study Lakes

Mean concentrations of chlorophyll *a* varied from 1.8 to 3.4 $\mu g\ l^{-1}$ in the study lakes. McLaren and Otter Lakes had mean chlorophyll *a* concentrations below 2 $\mu g\ l^{-1}$ (1.8 and 1.9 $\mu g\ l^{-1}$ respectively) while Haines and Horseshoe Lakes had mean values exceeding 3 $\mu g\ l^{-1}$ (3.4 and 3.1 $\mu g\ l^{-1}$ respectively). Oastler, Little Otter and Rankin Lakes had mean concentrations of chlorophyll *a* within the range 2 to 3 $\mu g\ l^{-1}$ (2.6, 2.2 and 2.3 respectively).

Georgian Bay

Concentrations of chlorophyll *a* ranged from .7 to 4.7 $\mu g\ l^{-1}$ with an overall mean value of 2.6 $\mu g\ l^{-1}$.

4.0 DISCUSSION

4.1 GENERAL WATER QUALITY

In general, the study lakes exhibited the low chemical concentrations typical of Precambrian Shield Lakes. A comparative summary of lake water quality for various Precambrian Shield waters including those from the present study is provided in Table 4.1.1. As indicated in the table, the waters studied are similar to other dilute freshwater environments in Ontario.

With the exception of Otter Lake which appeared significantly more dilute, the study lakes were similar to each other in terms of chemical concentrations and thermal stratification was evident at all deeper stations. Thermal stratification is extremely important in determining the vertical distribution of chemical species and dissolved gases in a lake since a well established thermocline effectively isolates the surface water (epilimnion) from the bottom water (hypolimnion) acting as a barrier to vertical diffusion. In this regard it should be noted that most parameters showed significant variation between surface and bottom waters with the highest concentrations generally occurring at bottom - indicating significant recycling of materials in the hypolimnetic waters.

Areas of major concern in the study lakes were found to be low pH, relatively high concentrations of nutrients and low dissolved oxygen concentrations.

With the exception of Otter and Little Otter Lakes, which exhibited the lowest surface pHs (range - 6.00 to 6.40), pH in the study lakes was slightly above 7 (neutral) at surface (range-7.01 to 7.51)

TABLE 4.1.1

COMPOSITION OF DILUTE LAKE WATERS FOR SELECTED IONS

LAKE	SECCHI DISC (metres)	CONDUCTIVITY (μmho cm^{-1})	pH	ALKALINITY (mg $l^{-1}CaCO_3$)	TOTAL P (μg l^{-1})	NO_3 (mg l^{-1})	SULPHATE (mg l^{-1})	CALCIUM (mg l^{-1})	REFERENCE
Haines	2.1 - 4.0	52 - 69	6.1 - 7.2	7 - 11	10 - 26	<.01-.24	7 - 10	4 - 5	present study
Horseshoe	2.4 - 6.0	45 - 85	6.4 - 7.6	7 - 15	7 - 30	<.01-.10	7 - 10	4 - 6	present study
McLaren	1.6 - 3.9	60 - 61	7.2 - 7.6	10 - 11	10 - 16	.01	10	6	present study
Oastler	1.8 - 3.6	53 - 69	6.3 - 7.3	10 - 13	9 - 38	<.01	9 - 10	4 - 5	present study
Otter	3.6 - 5.6	31 - 43	5.5 - 6.3	8 - 18	3 - 23	<.01-.17		8 - 9	present study
Little Otter	2.0 - 3.8	52 - 60	6.2 - 6.4	8 - 12	10 - 27	.03-.06	8 - 10	4 - 6	present study
Rankin	3.6 - 5.8	56 - 58	6.1 - 7.1	8 - 11	15 - 25	<.01-.13	9 - 10	6 - 7	present study
Georgian Bay	2.1 - 3.9	76 - 84	7.1 - 7.6	24 - 28	13 - 19	<.01-.08	10	10 - 11	present study
Temagami	4.6 -11.9	39 -156	6.0 - 7.4	4 - 24	1 - 68	<.01-.42	13 - 40	5 - 15	Conroy and Keller, 1974
Superior	10	79 - 90	7.4	32	>1	--	3.2	12.4	Beeton and Chandler, 1967
Huron	9	192	8.1	50	--	--	9.7	--	Beeton and Chandler, 1967
E. L. A. *	--	19	5.6 - 6.7	3.1	--	<.02	3	1.6	Armstrong and Schindler, 1971
Sudbury Lakes	5.0 -12.0	52 - 80	5.0 - 7.8	1.5 - 28	--	.1-1.25	7 - 23	.6 - 13	Conroy, 1971

* Experimental Lakes Area

however, a great pH reduction occurred in the bottom waters - undoubtedly due to the production of organic acids and/or carbon dioxide from the decomposition of organic matter. The lowest bottom water pH values were recorded in Otter Lake (5.46 to 5.55) and are of particular concern since it has been shown that a decline in a fishery can be expected when pH falls below 5.5 (Jenson and Snekvik, 1972). Bottom water pH was considerably higher in the other lakes with no values falling below 6.0, however, Haines, Rankin and Little Otter Lakes as well as certain stations in Horseshoe Lake and Oastler Lake exhibited values below the range of 6.5 to 8.5 considered essential for the protection of fish and other aquatic life (M.O.E., 1972).

The relatively high concentrations of nutrients, particularly phosphorous, at certain stations are of concern and are thought to be due to inputs from shore facilities. It has been shown that Precambrian Shield Lakes are particularly vulnerable to adverse changes resulting from such artificial inputs of nutrients. It has been indicated (see Michalski and Conroy, 1972) that nuisance levels of algae may materialize in soft-water Precambrian Shield lakes when mean total phosphorous concentrations during the ice-free season exceed 20 $\mu g\ l^{-1}$. In this regard, a severe algae bloom occurred in Little Otter Lake during 1971 (see Michalski and Conroy, 1973). The authors reported that the lake returned to an oligotrophic condition after the source of enrichment had been curtailed.

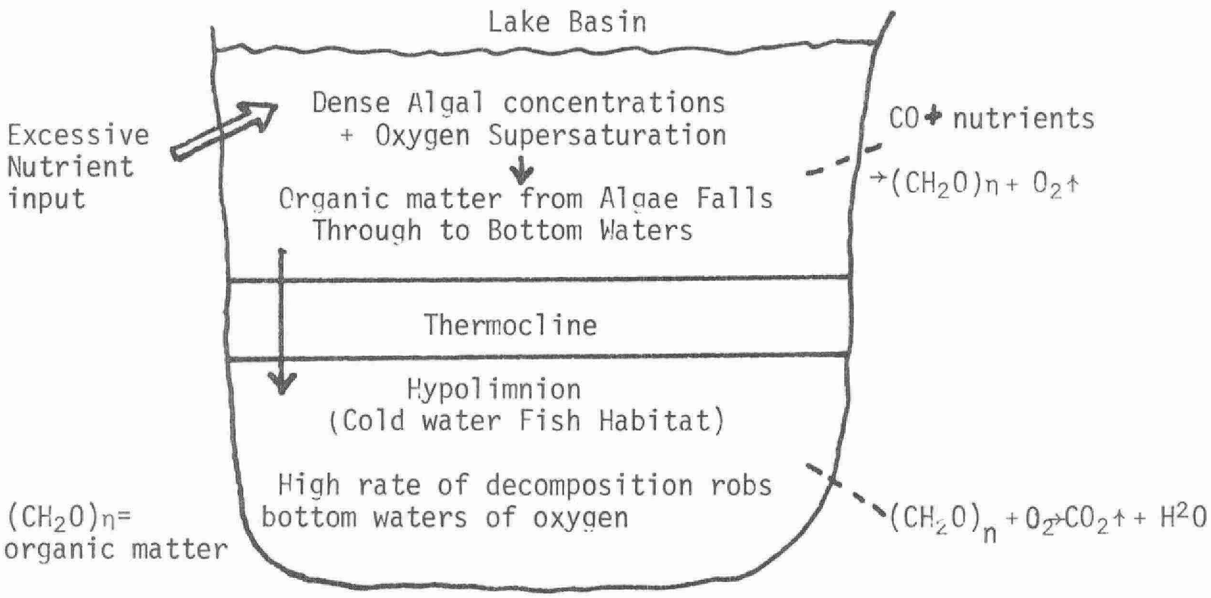
With the exception of McLaren Lake, all lakes had at least one station exceeding the 20 $\mu g\ l^{-1}$ criterion in the bottom waters. The highest concentration of total phosphorous (39 $\mu g\ l^{-1}$) was recorded in the bottom water of Oastler Lake. The relatively high concentrations of nitrogen at some stations (particularly the deeper waters of Horseshoe and Oastler Lakes) and localized high concentrations of iron are of further concern.

When concentrations of dissolved oxygen fall below 4 mg l^{-1}, fish populations are jeopardized since they require oxygen for breathing. With the exception of stations 2, 3 and 4 in Otter Lake, all stations exceeding 7 metres in depth had bottom water dissolved oxygen concentrations closely approaching or below 4 mg l^{-1}. In some cases, values below 1 mg l^{-1} were recorded. These low concentrations of dissolved oxygen are undoubtedly caused by the decomposition of organic matter, and are probably a result of nutrient additions from shoreline developments. The operating mechanism causing this oxygen deficiency is depicted in Figure 4.1.1. In this regard high mean chlorophyll a concentrations in Haines and Horseshoe Lakes (indicating dense algal concentration) corresponded to low bottom water dissolved oxygen conditions.

FIGURE 4.1.1

SIMPLIFIED REPRESENTATION OF MECHANISM

CAUSING BOTTOM WATER DISSOLVED OXYGEN DEPLETION



An additional concern related to low bottom water dissolved oxygen concentrations is the potential for the recycling of nutrients from bottom sediments. Brydges, 1971, has shown that when the mud-water interface is depleted of oxygen the nutrients which are incorporated in the sediment, particularly phosphorous, begin to be released and become available to phytoplankton during periods of destratification. This can lead to an increase in algal biomass to the extent that nuisance blooms of algae occur during the spring and fall mixing periods. The decomposition of dead cells from such a bloom can further deplete the oxygen supply in the hypolimnion.

The portion of Georgian Bay investigated exhibited generally good water quality. Concentrations of nutrients were within acceptable levels and abundant dissolved oxygen was present throughout the water column. Concentrations of other parameters were generally within the expected range.

4.2 TROPHIC STATUS

Lakes in north temperate regions of the world can be divided into three intergrading categories - Oligotrophic, Mesotrophic and Eutrophic, based on the degree of biological activity.

Oligotrophic lakes are poorly supplied with nutrients and correspondingly support meagre plant growth. These lakes are generally deep, highly transparent, relatively unproductive and well supplied with oxygen in their deeper waters. Cold water fish species such as lake trout, whitefish and herring generally predominate.

Eutrophic lakes are on the opposite end of the scale, having a rich supply of nutrients and abundant plant growth. Normally, these waters are turbid, warm and productive, and often show dissolved oxygen depletions in their deeper waters due to the decomposition of organic matter. Warm water fish species such as walleye, pike and perch usually predominate.

Mesotrophic lakes are intermediate between an oligotrophic and eutrophic status. They have a moderate supply of nutrients and therefore a moderate degree of plant growth and biological activity. Often, both warm water and cold water fish species are present.

From the time of their formation, lakes progress toward a eutrophic status. This process is termed lake ageing and eventually causes lakes to become marshes and finally dry land. The natural process of lake ageing is extremely slow - so slow that a significant change in the trophic status of a lake would not occur in centuries of time.

Man's activity can greatly accelerate the eutrophication process by means of artifical inputs of nutrients. If lakes are used as a sink for nutrient-rich sewage wastes generated by shoreline activity, oligotrophic lakes (nutrient impoverished) can become eutrophic (nutrient enriched) in a very short period of time. Evidence of culturally eutrophied lakes is becoming more and more evident as populations multiply and recreational uses of lakes increase (Vallentyne, 1974).

For most water oriented recreational activities, particularly swimming, boating and aesthetics, oligotrophic lakes are held in much higher esteem than eutrophic lakes. Eutrophic lakes are normally low quality recreational waters and it is apparent that emphasis should be given to the prevention of cultural eutrophication from man's activity.

Vallentyne, 1969, has indicated that in general, lakes exhibiting Secchi disc transparency readings of less than 3 metres are eutrophic while lakes with Secchi disc readings exceeding 6 metres are oligotrophic. By this criteria, Secchi disc readings from Haines and Oastler lakes (mean values of 2.9 and 2.7 metres respectively) indicate an early eutrophic status while Secchi disc values for the remaining lakes (range 3.0 to 4.7) suggest a mesotrophic status.

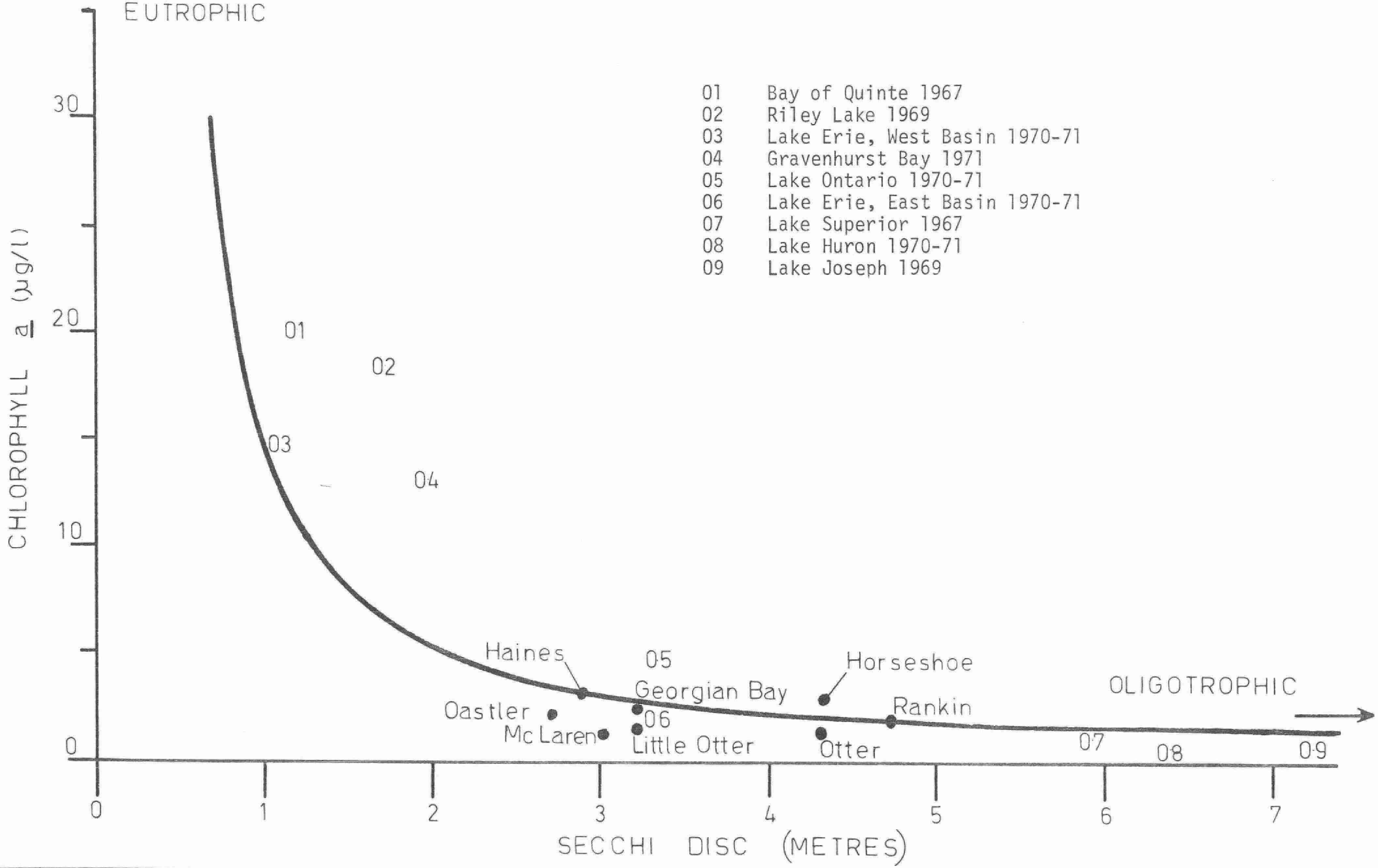
Secchi disc values for Georgian Bay (Mean 3.2 m) also indicate a mesotrophic status. The recorded values appear somewhat lower than expected for Georgian Bay and, in fact, are very similar to values reported for Midland Bay (2.0 - 5.0 m) - an area of deteriorating water quality (Michalski, 1974).

The concentration of chlorophyll a, the photosynthetic green pigment in plants, can be used as an indication of the extent of biological activity in a lake at the time of sampling. Experience has indicated (see Michalski and Conroy, 1972), that chlorophyll a values below 5 $\mu g\ l^{-1}$ indicate low to moderate algal densities characteristic of oligotrophic lakes, while concentrations greather than 10 $\mu g\ l^{-1}$ reflect high algal densities characteristic of eutrophic lakes. Mean concentrations of chlorophyll a in the study lakes and Georgian Bay ranged from 1.8 to 3.4 $\mu g\ l^{-1}$, indicating an oligrorophic status in all cases. The mean chlorophyll a concentration for the studied portion of Georgian Bay (2.5 $\mu g\ l^{-1}$) was slightly above the concentration considered typical of the offshore waters of Georgian Bay (2.0 $\mu g\ l^{-1}$ or less, Michalski, 1974).

The chlorophyll a and Secchi disc data are in poor agreement since Secchi disc values indicate a eutrophic to mesotrophic status while chlorophyll a values indicate an oligotrophic status.

Ministry of the Environment staff have shown a near hyperbolic relationship between chlorophyll a concentrations and Secchi disc readings which can be used to bracket the trophic status of a lake. Figure 4.2.1. is a graph of this relationship with the values for the study area included. The position of the study lakes on the graph indicates a mesotrophic status for all with Horseshoe, Otter and Rankin Lakes appearing to be in the early stages of mesotrophy while Oastler, Haines, McLaren and Little Otter Lakes as well as Georgian Bay appear in a more advanced stage.

FIGURE 4.2.1 THE RELATIONSHIP BETWEEN CHLOROPHYLL a AND SECCHI DISC AS DETERMINED FOR ONTARIO LAKES



Further evidence of eutrophication in the study lakes is provided by the clinograde dissolved oxygen distributions observed at most deeper stations. Clinograde dissolved oxygen profiles are generally considered typical of eutrophic lakes. It should be noted that some of the clinograde curves also qualify for classification as positive heterograde - considered indicative of mesotrophy by a number of authors (see Michalski, 1971).

As previously indicated, Brydges, 1971, has shown that under anaerobic conditions, nutrients may be released to the bottom waters from the sediments. The ratio of total iron to total phosphorous in the bottom waters provides an indication of the extent of this recycling process, since the selective release of phosphorous increases the phosphorous concentration - reducing the iron to phosphorous ratio. A summary of iron: phosphorous ratios at stations in the study area exhibiting anaerobic conditions in their bottom waters is presented in Table 4.2.1.

Table 4.2.1

FE:P RATIOS IN THE STUDY LAKES

Location	Fe:P Ratio
Haines Lake - station 1	38.5
Haines Lake - station 3	40.0
Horsehoe Lake - station 6	115.4
Oastler Lake - station 1	38.9
Oastler Lake - station 2	39.5
Otter Lake - station 1	10.9

As indicated in Table 4.2.1, iron to phosphorus ratios ranged from 10.9 to 115.4, similar to the range reported by Brydges, 1971, for six lakes unaffected by cottages or agriculture (18 to 71). It appears that significant recycling of nutrients in the bottom waters of the study lakes is not occurring at this time.

Michalski and Conroy, 1972 have developed a water quality ranking system which provides an indication of a lakes ability to withstand development. The ranking system is based on six parameters - mean depth, Secchi disc, chlorophyll a, dissolved oxygen, morphoedaphic index and iron to phosphorus ratio and lakes are ranked on a scale of 0 (poorest water quality) to 10 (best water quality) - see Michalski and Conroy, 1972. Table 4.2.2 provides a summary of water quality rankings for the study waters. For comparative purposes, data for Little Otter Lake during the 1971 algae bloom and for Gold Lake - a high water quality lake used in the development of the ranking system are included in the table.

It is apparent from Table 4.2.2 that in terms of water quality the study waters are far removed from the eutrophic conditions existing in Little Otter Lake during the algal bloom of 1971. However, it should be noted that they rank significantly lower than high water quality Gold Lake.

The intermediate rank of the study waters is a further indication of a mesotrophic status. The low rankings of Haines, Oastler and Little Otter Lakes are of particular concern, since they indicate extreme vulnerability to enrichment from shoreline activity.

TABLE 4.2.2

RANKING OF SELECTED LAKES BASED ON THE LAKE ALERT FORMAT

LAKE	YEAR	MEAN DEPTH	SECCHI DISC	CHLOROPHYLL a	DISSOLVED OXYGEN	MORPHOEDAPHIC INDEX	FE/P RATIO	AVERAGE RANK
Haines	1973	2.4	5.2	9.6	0	7.1	2.7	4.5
Horseshoe	1973	1.6	8.3	9.7	0	6.5	10	6.0
McLaren	1973	--	5.4	10	10	--	--	8.5
Oastler	1973	2.0	4.8	9.8	0	6.6	2.7	4.3
Otter	1973	3.4	8.3	10	0	9.1	0	5.1
Little Otter	1973	0	5.9	9.9	3.3	0	--	3.8
Rankin	1973	2.1	9.1	9.9	3.3	7.0	--	6.3
Georgian Bay	1973	--	5.9	9.8	3.3	--	--	6.3
[1]Little Otter (during Algae bloom)	1971	0	0	0	3.3	0	--	.7
[2]Gold	1969	10	10	10	10	10	--	10

1 - from Michalski and Conroy, 1973

2 - from Michalski and Conroy, 1972.

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A P P E N D I X   A

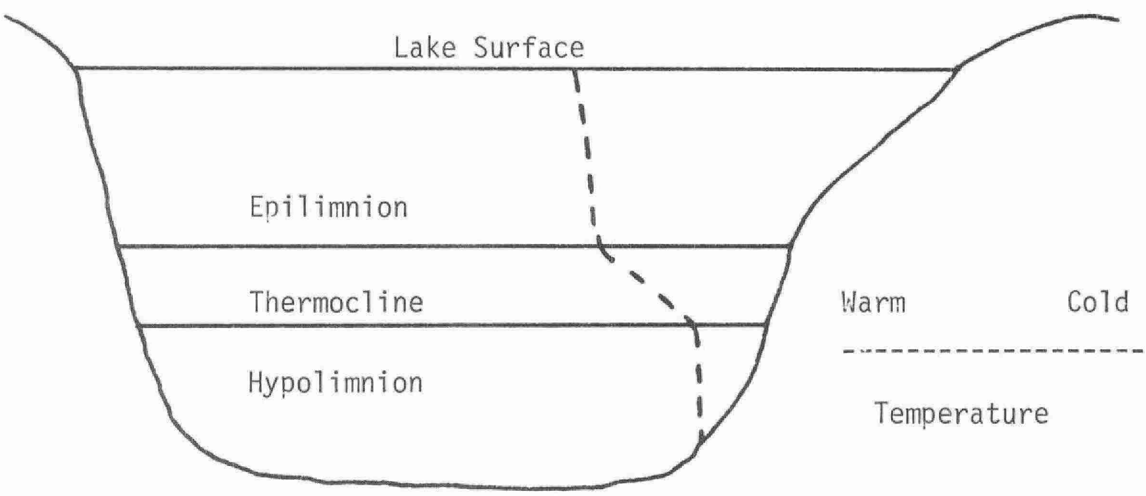
G L O S S A R Y

GLOSSARY

EPILIMNION - lakes which show thermal stratification have three distinct layers. The upper layer of water in which the temperature is relatively uniform is the epilimnion (see Figure A).

FIGURE A

Sketch of cross-section of theoretical lake during thermal stratification indicating water layers and temperature distribution.



EUPHOTIC ZONE - the intensity of light diminishes as it passes through water until at some depth there is insufficient light to carry on photosynthesis. This zone of significant light penetration is the euphotic zone.

EUTROPHIC - lakes are classified into three catagories on the basis of the biological activity - those with high biological activity and large nutrient concentrations are eutrophic. Characteristically eutrophic lakes are shallow, warm and highly turbid (see oligotrophic, mesotrophic and trophic status).

EUTROPHICATION - the process by which lakes become increasingly enriched in nutrients. It refers to the entire complex of changes which accompany nutrient enrichment including dense growth of algae and aquatic weeds.

HYPOLIMNION - the uniformly cold layer of water lying beneath the thermocline in thermally stratified lakes, (see Figure A).

MESOTROPHIC - those lakes with a moderate supply of nutrients and moderate biological activity, i.e. a trophic status lying between oligotrophic and eutrophic.

OLIGOTROPHIC - lakes with a meagre supply of nutrients and low biological activity. Characteristically oligotrophic lakes are deep, cold water, highly transparent bodies of water.

pH - a measure of acidity/alkalinity on a scale from 0-14 where 7.0 is neutral and 6.9-0 indicates increasing acidity and 7.1 to 14 increasing alkalinity.

strongly acid	acid	neutral	basic	strongly basic
0-3.9	4-6.9	7.0	7.1-10	10.1-14
	natural water			

THERMOCLINE - the mid layer of water in thermally stratified bodies of water in which the rate of change of temperature is a maximum.

TROPHIC STATUS - lakes are classified on the basis of the degree of nutrients enrichment and biological acitivity into three integrating types; oligotrophic, mesotrophic and eutrophic. Additions of nutrients to infertile lakes (oligotrophic) tned to make them mesotrophic and with continued enrichment they will become eutrophic.

APPENDIX B

DATA TABLES

TABLE I

RESULTS OF CHEMICAL ANALYSES

LAKE	STATION	DATE	DEPTH (metres)	pH	ALK. mg l^{-1}	HARD. mg l^{-1}	COND. μ mho cm^{-1}	SO_4 mg l^{-1}	Ca mg l^{-1}	Mg mg l^{-1}	Na mg l^{-1}	K mg l^{-1}
Haines	1	21/8/73	1.0	7.17	9	19	58	9	5	1	3	1.2
		21/8/73	12.0	6.21	10	18	58	9	4	2	3	1.3
	2	21/8/73	1.0	7.15	8	16	52	8	4	1	3	1.2
		21/8/73	17.0	6.29	10	17	55	10	5	1	3	1.2
	3	21/8/73	1.0	7.03	11	20	56	8	5	2	3	1.2
		21/8/73	11.0	6.11	7	18	69	7	4	2	3	1.3
Horseshoe	1	22/8/73	1.0	7.34	7	17	48	7	4	2	3	1.2
		22/8/73	18.0	6.44	11	20	56	10	6	1	3	1.2
	2	22/8/73	1.0	7.21	12	19	46	8	4	2	3	1.2
		22/8/73	4.0	7.09	9	16	46	8	4	1	3	1.2
	3	22/8/73	1.0	7.11	10	16	47	8	4	2	3	1.3
		22/8/73	5.0	7.10	12	18	45	8	4	2	3	1.1
	4	22/8/73	1.0	7.21	9	18	48	8	5	1	3	1.0
		22/8/73	7.0	6.80	12	18	55	10	5	1	4	1.0
	5	22/8/73	1.0	7.51	13	16	49	8	4	1	3	1.0
		22/8/73	8.0	6.51	15	18	62	8	4	2	4	1.1
	6	22/8/73	1.0	7.50	10	18	49	8	5	1	4	1.2
		22/8/73	17.0	7.64	15	21	85	9	6	1	6	1.4
McLaren	1	23/8/73	1.0	7.59	11	20	61	10	6	1	3	1.2
		23/8/73	3.0	7.25	10	20	60	10	6	1	3	1.2

TABLE I (Continued)

LAKE	STATION	DATE	DEPTH (metres)	pH	ALK. mg l^{-1}	HARD. mg l^{-1}	COND. μ mho cm^{-1}	SO_4 mg l^{-1}	Ca mg l^{-1}	Mg mg l^{-1}	Na mg l^{-1}	K mg l^{-1}
Oastler	1	22/8/73	1.0	7.01	13	17	53	10	4	1	3	1.1
		22/8/73	6.0	7.01	12	20	55	9	5	2	4	1.1
	2	22/8/73	1.0	7.31	13	19	61	10	5	2	3	1.0
		22/8/73	18.0	6.34	10	20	69	10	4	2	3	1.1
Otter	1	23/8/73	1.0	6.20	13	20	31	8	4	2	2	1.3
		23/8/73	12.0	5.50	18	18	43	9	4	2	1	1.0
	2	23/8/73	1.0	6.00	13	17	31	8	6	1	1	1.0
		23/8/73	23.0	5.46	12	20	32	8	5	2	1	1.0
	3	23/8/73	1.0	6.25	8	14	31	8	3	1	1	.9
		23/8/73	29.0	5.55	10	18	34	9	4	2	1	1.0
	4	23/8/73	1.0	6.27	10	15	31	9	4	1	1	.9
		23/8/73	27.0	5.50	12	18	33	9	3	2	1	1.0
Little Otter	1	23/8/73	1.0	6.40	8	18	53	10	4	2	3	1.2
		23/8/73	4.0	6.25	11	19	58	10	4	2	3	1.2
	2	23/8/73	1.0	6.40	10	20	60	10	5	2	3	1.3
		23/8/73	5.0	6.30	12	20	52	8	6	1	4	1.3
Rankin	1	30/8/73	1.0	7.11	8	22	56	10	7	1	3	1.1
		30/8/73	13.0	6.15	11	24	58	10	6	2	3	1.2
	2	30/8/73	1.0	7.08	9	24	56	10	6	2	3	1.1
		30/8/73	13.0	6.20	10	25	58	9	6	2	3	1.2
Georgian Bay	1	30/8/73	1.0	7.60	25	37	76	10	11	2	2	1.1
		30/8/73	6.0	7.20	28	38	80	10	10	3	2	1.1
	2	30/8/73	1.0	7.62	24	36	80	10	11	2	2	1.0
		30/8/73	13.0	7.13	27	39	84	10	11	3	2	1.1

TABLE II

RESULTS OF CHEMICAL ANALYSES

LAKE	STATION	DATE	DEPTH (metres)	NITROGEN (mg l^{-1}) NH_3	Kjel	NO_3	NO_2	PHOSPHORUS (mg l^{-1}) Total	Soluble	IRON (mg l^{-1}) Total	Soluble
Haines	1	21/8/73	1.0	.05	.36	<.01	.003	.014	.004	.20	.15
		21/8/73	12.0	.04	.34	.04	.004	.026	.001	1.0	.20
	2	21/8/73	1.0	.03	.25	<.01	.002	.010	.001	.10	.05
		21/8/73	17.0	<.01	.24	.10	.002	.015	.001	.40	.20
	3	21/8/73	1.0	.03	.40	.16	.003	.014	.006	.20	.10
		21/8/73	11.0	.02	.38	.24	.005	.020	.002	.80	.25
Horseshoe	1	22/8/73	1.0	<.01	.25	.05	.001	.007	.004	.05	<.05
		22/8/73	18.0	.26	.72	.10	.004	.030	.001	.90	.25
	2	22/8/73	1.0	.02	.39	<.01	.003	.026	.009	.25	.15
		22/8/73	4.0	.01	.31	<.01	.002	.014	.001	.20	.10
	3	22/8/73	1.0	.01	.30	<.01	.002	.007	.001	.20	.15
		22/8/73	5.0	.03	.31	<.01	.002	.010	.001	.40	.25
	4	22/8/73	1.0	.02	.31	<.01	.002	.012	.003	.05	<.05
		22/8/73	7.0	.08	.34	<.01	.002	.012	.001	.25	.05
	5	22/8/73	1.0	.02	.31	<.01	.003	.010	.003	.05	.05
		22/8/73	8.0	.09	.33	.02	.003	.012	.001	.35	.05
	6	22/8/73	1.0	.01	.31	.04	.001	.018	.003	.10	<.05
		22/8/73	17.0	.41	.78	.01	.009	.026	.004	3.0	.85
McLaren	1	23/8/73	1.0	.02	.28	.01	.002	.010	.002	.10	.10
		23/8/73	3.0	<.01	.36	.01	.002	.016	.002	.15	.05
Oastler	1	22/8/73	1.0	.01	.28	<.01	.002	.010	.001	.15	.10
		22/8/73	6.0	.02	.37	<.01	.002	.009	.001	.35	.10
	2	22/8/73	1.0	.01	.31	<.01	.002	.020	.005	.10	.10
		22/8/73	18.0	.19	.52	<.01	.012	.038	.012	1.5	1.0

TABLE II (Continued)

LAKE	STATION	DATE	DEPTH (metres)	NITROGEN (mg l^{-1})				PHOSPHORUS (mg l^{-1})		IRON (mg l^{-1})	
				NH_3	Kjel	NO_3	NO_2	Total	Soluble	Total	Soluble
Otter	1	23/8/73	1.0	.01	.28	--	.001	.013	.003	.10	<.05
		23/8/73	12.0	.13	.44	--	.005	.023	.001	.25	.09
	2	23/8/73	1.0	.01	.30	--	.001	.006	.001	<.05	<.05
		23/8/73	23.0	.02	.27	--	.005	.018	.016	<.15	<.05
	3	23/8/73	1.0	.01	.26	<.01	.003	.009	.001	<.05	<.05
		23/8/73	29.0	<.01	.23	.17	.002	.014	.001	.35	.15
	4	23/8/73	1.0	.01	.23	<.01	.003	.006	.001	<.05	<.05
		23/8/73	27.0	<.01	.19	.13	.002	.003	.001	.05	.05
Little Otter	1	23/8/73	1.0	.02	.24	.04	.001	.010	.001	.15	.05
		23/8/73	4.0	.01	.25	.03	.001	.010	.001	.10	<.05
	2	23/8/73	1.0	.01	.27	.06	.001	.016	.001	.15	<.05
		23/8/73	5.0	.01	.38	.04	.001	.027	.002	.30	.10
Rankin	1	30/8/73	1.0	.01	.36	<.01	.002	.015	.001	<.05	<.05
		30/8/73	13.0	.03	.30	.13	.005	.022	.003	.50	.25
	2	30/8/73	1.0	.01	.29	<.01	.001	.021	.006	<.05	<.05
		30/8/73	13.0	.03	.27	.13	.004	.025	.007	.60	.20
Georgian Bay	1	30/8/73	1.0	.05	.32	<.01	.003	.014	.002	.10	.05
		30/8/73	6.0	.04	.30	.05	.003	.013	.005	.05	<.05
	2	30/8/73	1.0	.05	.36	.02	.004	.013	.005	.05	<.05
		30/8/73	13.0	.06	.40	.08	.004	.019	.003	.20	<.05

TABLE III

RESULTS OF DISSOLVED OXYGEN AND TEMPERATURE MEASUREMENTS

STATION	DEPTH (metres)	DISSOLVED OXYGEN % saturation	DISSOLVED OXYGEN mg l^{-1}	TEMPERATURE (°C)
HAINES LAKE				
1	1.0	98	8.6	20.2
	3.0	98	8.6	20.2
	4.0	15	1.4	15.5
	5.0	34	3.4	13.2
	6.0	38	4.1	10.0
	7.0	35	4.0	8.3
	8.0	30	3.5	7.0
	10.0	12	1.4	6.0
	12.0	8	1.0	5.5
2	1.0	109	9.6	20.2
	4.0	108	9.5	20.2
	5.0	53	5.2	14.5
	6.0	58	6.0	12.2
	7.0	60	6.5	10.0
	8.0	50	5.8	7.5
	10.0	46	5.5	6.0
	17.0	36	4.4	5.0
3	1.0	112	9.9	20.2
	4.0	111	9.8	20.2
	5.0	66	6.6	13.5
	6.0	42	4.6	10.2
	7.0	37	4.2	8.5
	8.0	30	3.5	7.0
	10.0	9	1.1	6.0
	11.0	6	.7	5.7
HORSESHOE LAKE				
1	1.0	104	8.8	22.2
	3.0	109	9.3	22.2
	6.0	108	9.2	22.2
	7.0	60	5.7	16.0
	8.0	50	5.0	14.0
	9.0			11.8
	10.0	47	5.1	9.9
	11.0			8.6
	12.0			7.0
	13.0	43	5.2	5.7
	14.0			5.0
	18.0	23	2.9	4.5
2	1.0	110	9.3	22.5
	2.0	109	9.3	22.2
	3.0	108	9.2	22.0
	4.0	108	9.2	22.0
3	1.0	112	9.4	22.7
	3.0	112	9.5	22.5

TABLE III (Continued)

STATION	DEPTH	DISSOLVED OXYGEN % saturation	DISSOLVED OXYGEN mg l^{-1}	TEMPERATURE (°C)
HORSESHOE LAKE (Continued)				
3	4.0			22.3
	5.0	108	9.8	18.4
4	1.0	120	10.2	22.4
	3.0	120	10.2	22.1
	5.0	118	10.0	22.1
	6.0	82	7.0	21.8
	7.0	59	5.5	17.4
5	1.0	124	10.5	22.2
	3.0	124	10.6	22.0
	6.0	124	10.6	22.0
	7.0	56	5.4	15.2
	8.0	45	4.6	13.0
6	1.0	127	10.8	22.3
	6.0	124	10.6	22.0
	7.0	73	7.3	14.0
	8.0	42	4.3	13.0
	9.0			11.5
	10.0	45	4.9	10.3
	12.0	25	2.8	9.5
	15.0	8	.9	7.6
	17.0	8	.9	6.5
McLARENS LAKE				
1	1.0	102	8.8	21.5
	3.0	102	8.8	21.5
OASTLER LAKE				
1	1.0	108	9.0	23.0
	3.0	108	9.1	22.5
	4.0	108	9.2	22.2
	5.0	33	3.0	18.0
	6.0	13	1.3	15.5
2	1.0	116	9.7	23.0
	5.0	112	9.5	22.0
	6.0	36	3.3	18.0
	7.0			13.0
	8.0	44	4.6	12.0
	9.0			9.5
	10.0	53	6.1	7.7
	12.0			6.6
	14.0	62	7.5	6.0
	17.0	57	7.0	5.0
	18.0	15	1.9	5.0

TABLE III (Continued)

STATION	DEPTH (metres)	DISSOLVED OXYGEN % saturation	DISSOLVED OXYGEN mg l^{-1}	TEMPERATURE (°C)
OTTER LAKE				
1	1.0	108	9.1	22.9
	5.0	112	9.4	22.9
	6.0	116	10.4	19.0
	7.0	82	8.1	14.2
	8.0	78	8.5	10.1
	9.0			8.5
	10.0	20	2.3	7.5
	11.0			6.2
	12.0	8	1.0	5.8
2	1.0	120	10.1	22.8
	5.0	120	10.1	22.8
	6.0	120	10.6	20.2
	7.0	108	9.9	18.0
	8.0	100	9.7	15.5
	9.0			13.5
	10.0			11.0
	11.0	80	8.7	10.0
	13.0			8.5
	15.0	74	8.6	7.5
	18.0			6.7
	23.0	72	8.7	6.0
3	1.0	124	10.4	22.7
	5.0	124	10.4	22.7
	6.0			17.0
	7.0			14.2
	8.0	100	10.6	11.3
	9.0			10.2
	10.0			9.9
	12.0	81	9.2	8.5
	15.0			7.2
	19.0	72	8.5	7.0
	29.0	60	7.2	6.1
4	1.0	126	10.6	22.6
	5.0	127	10.7	22.6
	8.0	120	10.4	21.2
	9.0	112		14.0
	10.0			11.0
	11.0	108	11.8	10.0
	12.0			9.0
	13.0	100	11.4	8.4
	15.0			7.0
	19.0	90	10.8	6.0
	27.0	88	10.8	5.2

TABLE III (Continued)

STATION	DEPTH (metres)	DISSOLVED OXYGEN % saturation	mg l^{-1}	TEMPERATURE (°C)
LITTLE OTTER LAKE				
1	1.0	126	10.6	22.8
	4.0	124	10.5	22.4
2	1.0	120	10.1	22.8
	3.0	122	10.3	22.4
	4.0	120	10.1	22.5
	5.0	98	8.3	22.5
RANKIN LAKE				
1	1.0	120	10.0	23.5
	4.0			23.5
	5.0	110	9.6	20.5
	6.0			16.5
	7.0	110	10.9	14.5
	8.0	78	8.0	12.5
	9.0			10.5
	10.0	40	4.4	9.5
	11.0			8.0
	13.0	25	2.9	8.0
2	1.0	110	9.1	24.0
	4.0			24.0
	5.0	104	9.0	21.0
	6.0			15.0
	7.0	100	10.5	11.5
	8.0	86	9.4	10.0
	9.0	45	5.0	9.0
	11.0	32	3.7	8.0
	13.0	32	3.7	8.0
GEORGIAN BAY				
1	1.0	120	9.9	24.0
	3.0			24.0
	5.0	100	8.5	22.0
	6.0	82	7.1	21.5
2	1.0	128	10.6	24.0
	3.0			23.0
	5.0	106	9.1	21.9
	8.0	96	8.3	21.0
	13.0	90	7.8	21.0

TABLE IV

SECCHI DISC READINGS AND CHLOROPHYLL a CONCENTRATIONS

STATION	DATE		SECCHI DISC (m)	CHLOROPHYLL a (μg/l)
HAINES LAKE				
1	June 4		3.3	1.9
	11		2.9	<1.0
	18		2.8	1.9
	25		2.7	2.4
	July 3		2.2	4.0
	8		2.4	5.2
	15		2.1	8.0
	29		2.7	3.4
	Aug. 6		3.2	3.6
	12		2.4	7.2
	19		3.2	2.3
	26		3.4	2.7
		Mean	2.8	3.6
2	June 4		3.3	1.8
	11		3.9	<1.0
	18		3.3	1.5
	25		3.3	3.0
	July 3		2.4	3.8
	8		2.6	4.1
	15		2.7	4.1
	29		3.2	4.0
	Aug. 6		3.3	4.7
	12		3.0	4.3
	19		4.0	1.9
		Mean	3.2	3.1
3	June 25		2.9	3.5
	July 3		2.2	1.9
	8		2.1	3.1
	15		2.2	4.4
	29		3.2	3.4
	Aug. 6		3.3	4.8
	12		2.4	5.8
	19		2.8	2.8
	26		3.4	2.5
		Mean	2.7	3.6

TABLE IV (Continued)

STATION	DATE		SECCHI DISC (m)	CHLOROPHYLL a (μg/l)
HORSESHOE LAKE				
1	June 4		3.0	2.2
	18		4.5	1.8
	25		6.0	2.9
	July 3		4.5	1.4
	8		4.8	3.3
	15		4.5	--
	Aug. 19		5.4	2.2
		Mean	4.7	2.3
2	June 4		3.0	1.9
	18		3.4	1.9
	25		4.5	--
	July 3		3.6	1.8
	8		3.6	3.6
	15		3.0	5.4
	Aug. 19		3.6	1.8
		Mean	3.5	2.7
3	June 4		2.4	2.7
	18		4.5	2.1
	25		4.8	2.5
	July 3		3.9	1.9
	8		3.6	5.4
	15		3.3	6.0
	Aug. 19		3.9	10.5
		Mean	3.8	4.4
4	June 4		3.0	2.7
	11		3.6	$<$1.0
	18		4.5	1.5
	25		4.8	2.6
	July 3		4.5	1.4
	8		5.1	3.2
	15		4.5	3.4
	Aug. 19		5.1	2.1
		Mean	4.4	2.2
5	June 18		4.5	1.3
	25		5.7	4.1
	July 3		4.2	2.4
	8		4.8	4.8
	15		4.8	7.2
	Aug. 19		4.8	3.3
		Mean	4.8	3.8

TABLE IV (Continued)

STATION	DATE		SECCHI DISC (m)	CHLOROPHYLL a (μg/l)
HORSESHOE LAKE (Continued)				
6	June 18		4.5	1.7
	25		4.5	3.9
	July 3		4.5	2.7
	8		4.5	4.1
	15		4.2	5.2
	Aug. 19		4.8	2.5
		Mean	4.5	3.4
McLAREN LAKE				
1	June 4		2.8	1.3
	11		3.2	<1.0
	17		3.9	1.5
	July 8		1.6	2.5
	15		3.4	2.8
		Mean	3.0	1.8
OASTLER LAKE				
1	June 11		3.4	4.3
	18		2.6	1.9
	25		2.4	3.1
	July 8		1.8	2.8
		Mean	2.6	3.0
2	June 11		3.2	<1.0
	18		3.6	2.6
	25		2.7	2.6
	July 8		2.1	2.6
	15		2.2	2.7
		Mean	2.8	2.3
OTTER LAKE				
1	June 4		3.9	1.4
	11		4.2	<1.0
	18		--	2.0
	25		--	3.7
	July 8		--	2.5
	14		4.2	2.3
	Aug. 5		4.8	2.8
	12		3.6	2.8
	19		3.6	2.3
	26		4.2	0.2
		Mean	4.1	2.1

TABLE IV (Continued)

STATION	DATE		SECCHI DISC (m)	CHLOROPHYLL a (μg/l)
OTTER LAKE (Continued)				
2	June 4		3.9	1.0
	11		4.5	1.1
	18		--	1.3
	25		--	2.5
	July 8		--	2.3
	14		4.2	2.3
	Aug. 5		4.8	2.4
	12		4.8	2.4
	19		4.8	2.0
	26		4.8	0.7
		Mean	4.5	1.8
3	June 4		3.9	1.2
	11		4.8	<1.0
	18		--	1.5
	25		--	2.0
	July 8		--	2.6
	14		4.2	2.1
	Aug. 5		5.1	2.5
	12		4.2	2.7
	19		3.9	1.8
	26		4.8	0.3
		Mean	4.4	1.8
4	June 4		5.6	0.8
	11		4.2	<1.0
	18		4.2	1.4
	25		4.8	2.5
	July 8		4.2	2.1
	15		4.4	1.8
	29		4.0	3.3
	Aug. 6		3.9	--
	12		4.5	2.0
		Mean	4.4	1.9
5	June 4		5.1	1.6
	11		4.4	<1.0
	18		3.9	1.5
	25		4.8	2.2
	July 8		4.0	2.1
	15		4.5	2.5
	29		3.6	2.9
	Aug. 6		3.6	2.1
	12		4.6	1.5
		Mean	4.3	1.9

TABLE IV (Continued)

STATION	DATE		SECCHI DISC (m)	CHLOROPHYLL a (μg/l)
LITTLE OTTER LAKE				
1	June 4		2.0	1.5
	11		3.0	1.5
	18		3.6	0.9
	25		3.8	2.2
	July 8		3.3	3.0
	15		3.0	2.3
	29		3.3	2.2
	Aug. 6		--	3.5
	12		3.4	2.6
		Mean	3.2	2.2
RANKIN LAKE				
1	June 4		5.0	1.3
	11		5.0	<1.0
	18		4.5	1.8
	25		5.0	2.2
	July 8		4.5	2.7
	15		3.6	4.0
	Aug. 6		5.2	3.9
	12		5.8	2.0
	19		5.1	2.1
		Mean	4.8	2.3
2	June 4		4.0	1.3
	11		4.6	1.3
	18		4.5	1.8
	25		5.2	2.3
	July 8		4.2	2.4
	15		3.9	3.2
	Aug. 6		5.1	4.0
	12		5.6	2.2
	19		5.4	2.1
		Mean	4.7	2.3
GEORGIAN BAY				
1	June 4		2.8	2.6
	11		3.4	1.9
	18		3.7	1.8
	July 2		2.6	1.3
	8		3.1	2.4
	15		2.1	2.7

TABLE IV (Continued)

STATION	DATE		SECCHI DISC (m)	CHLOROPHYLL *a* (μg/l)
GEORGIAN BAY (Continued)				
1	Aug. 6		3.6	3.6
	12		3.0	4.7
	19		3.7	2.6
	26		3.2	0.7
		Mean	3.1	2.4
2	June 4		3.4	3.6
	11		3.9	1.9
	18		3.7	2.3
	July 2		3.0	1.3
	8		3.2	2.5
	15		2.4	3.0
	Aug. 6		3.5	3.9
	12		2.9	4.3
	19		3.8	3.6
	26		3.4	1.0
		Mean	3.3	2.7

APPENDIX C

DISSOLVED OXYGEN

AND

TEMPERATURE PROFILES

FIGURE I

TEMPERATURE AND DISSOLVED OXYGEN DEPTH DISTRIBUTIONS

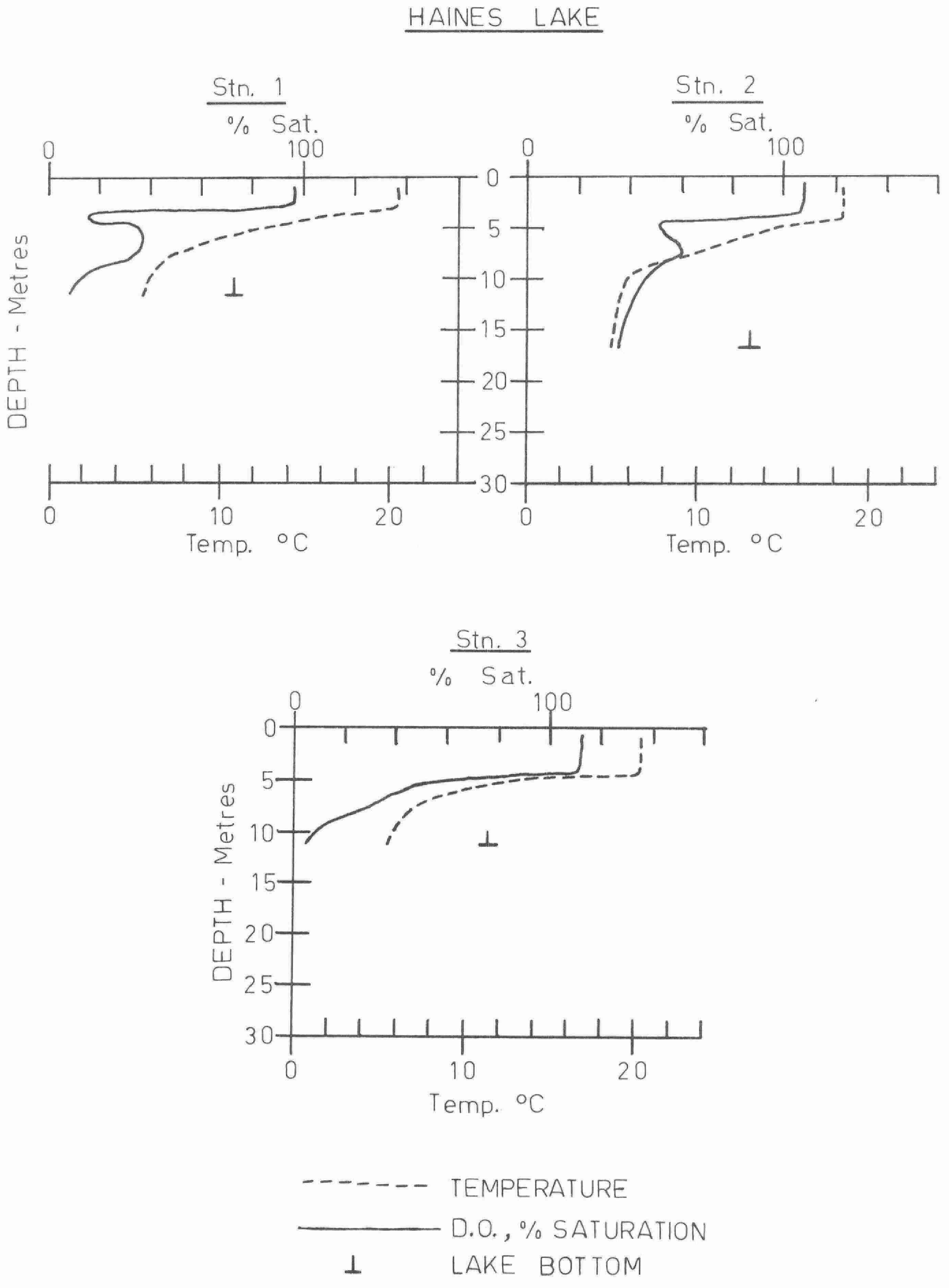


FIGURE I (CONT'D)

HORSESHOE LAKE

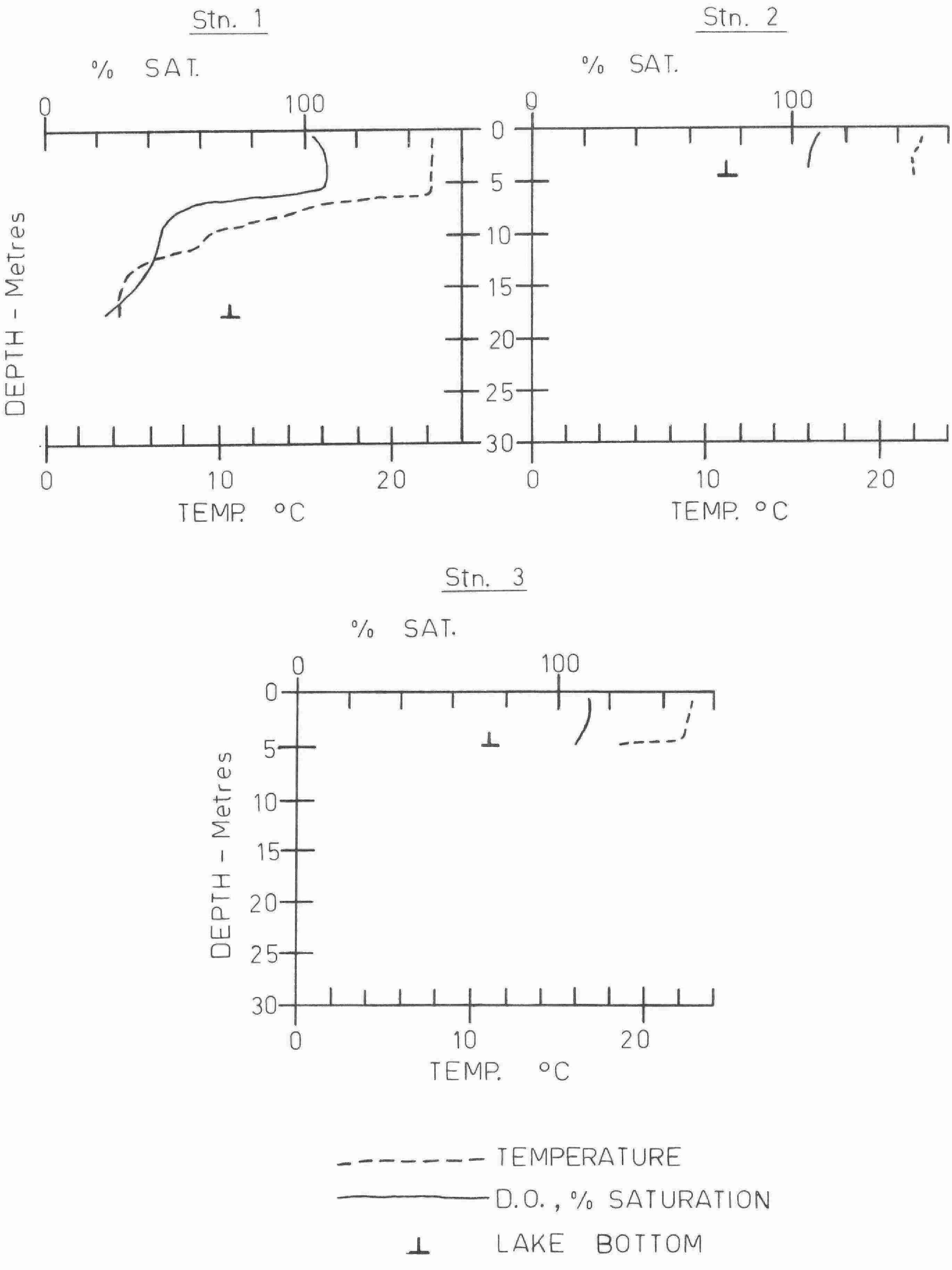


FIGURE I (CONT'D)

HORSESHOE LAKE

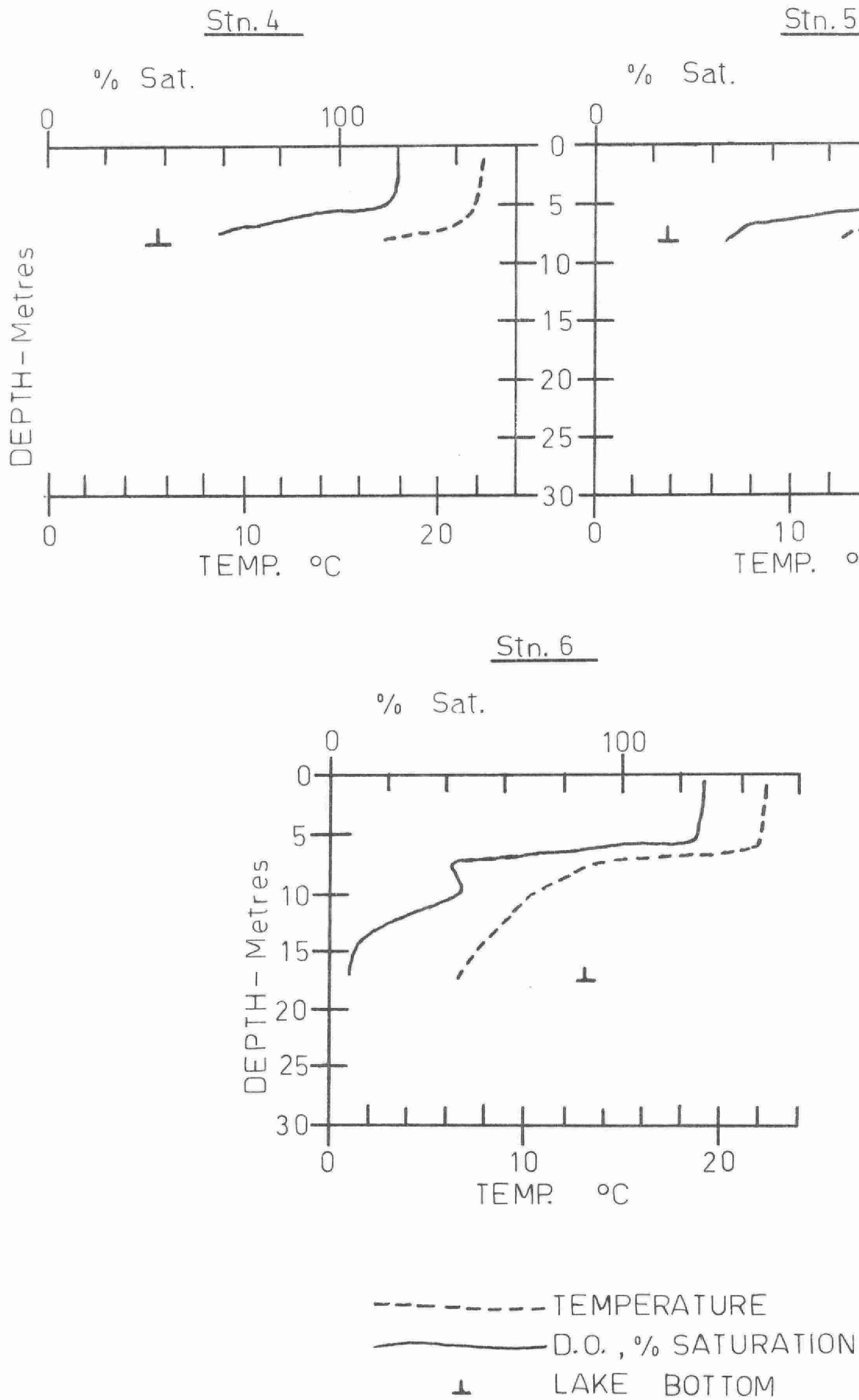


FIGURE I (CONT'D)

OTTER LAKE

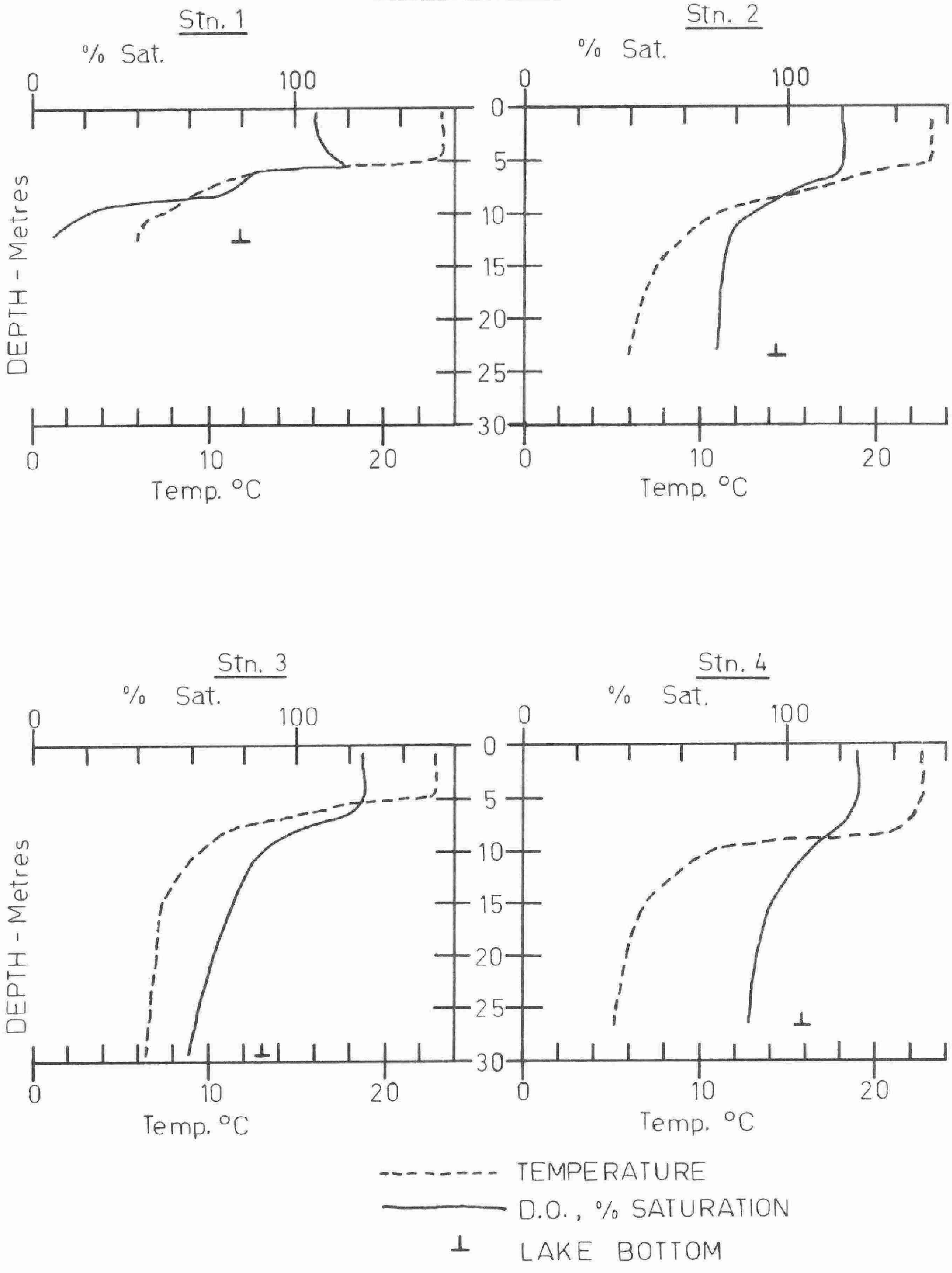


FIGURE I (CONT'D)

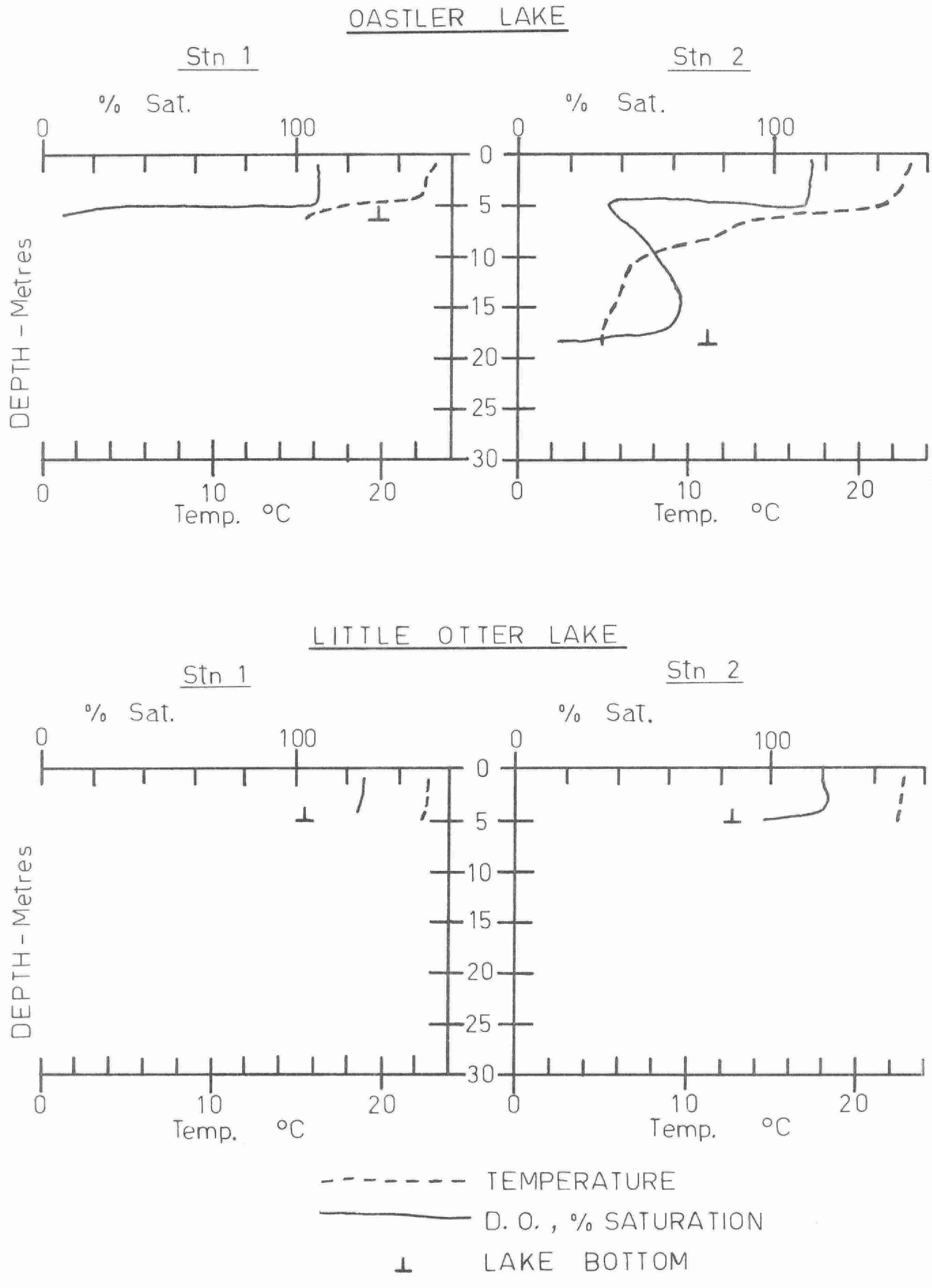
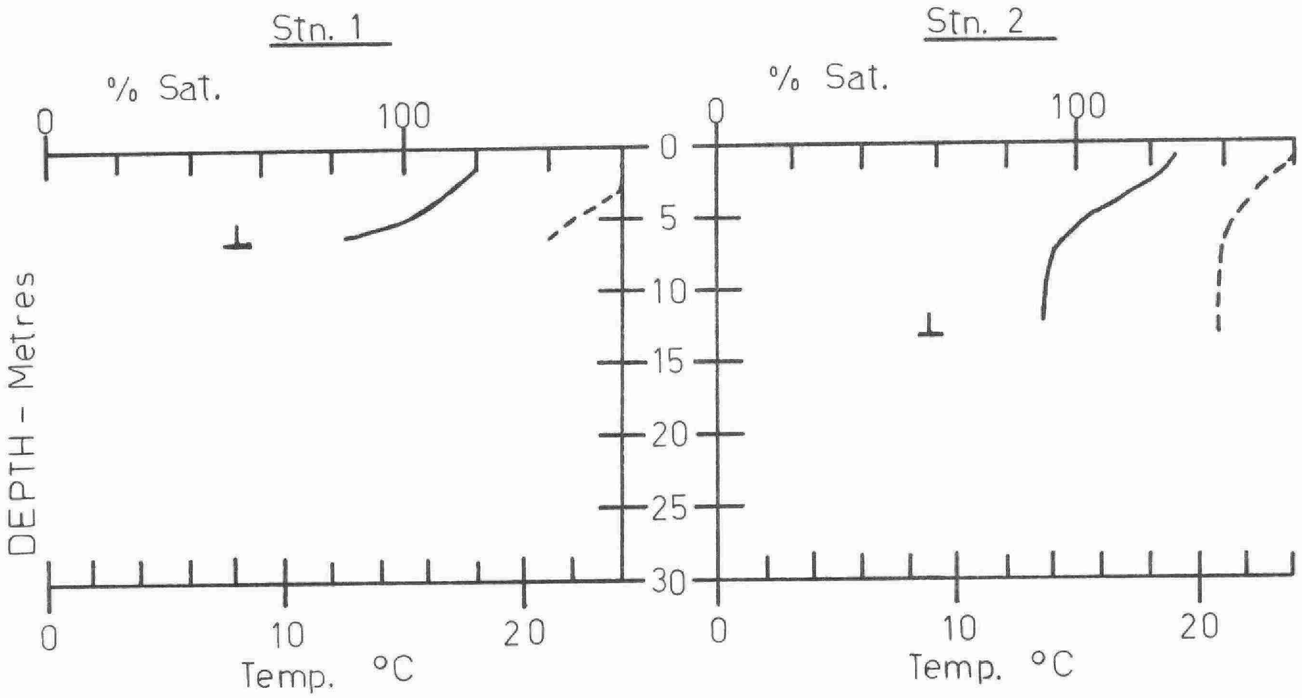
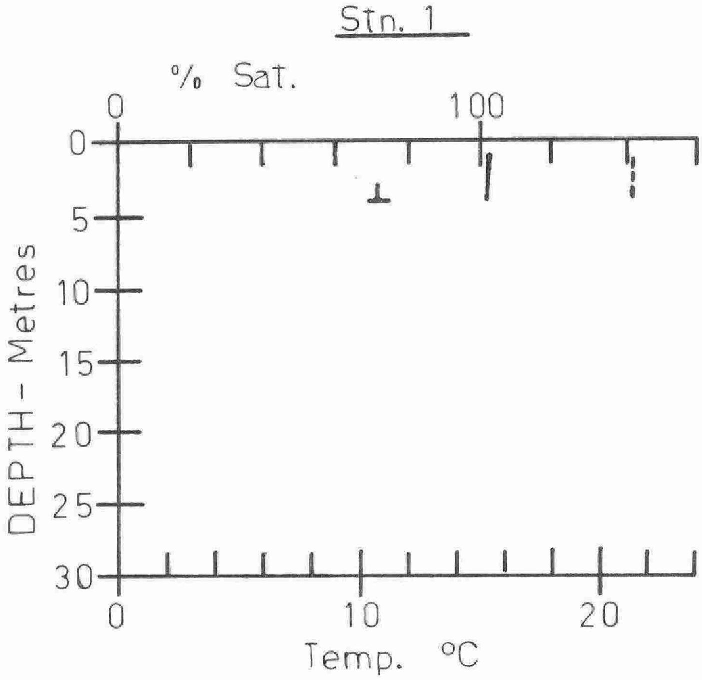


FIGURE I (CONT'D)

GEORGIAN BAY



McLARENS LAKE



TEMPERATURE
D.O., % SATURATION
⊥ LAKE BOTTOM

FIGURE I (CONT'D)